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AN ANALYSIS OF EASI-MINER TIME STUDY DATA AT OBED MOUNTAIN MINE

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by

J. K. Szymanski*, M. Heximer**, D. Veldhuis*** and G.H. LaRocque****

ABSTRACT

A time study of the Easi-Miner coaling operations at Obed Mountain Mine was conducted in November, 1986. For a given working condition, all components of the time cycle for a resource (Easi-Miner) and truck's network were evaluated. The time duration residuals of the particular network activities, when tested by the stabilized probability plot method showed a Weibull distribution. The parameters of the Weibull distributions from the time study data were done using an in house developed program.

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INTRODUCTION

The time study of "Easi-Miner" operation at Obed Mountain Mine was initiated in November 1986 as an initial step towards development of a computer based model of the mining operations using a continuous surface miner.

The study included monitoring of consecutive trucking activities associated with the "Easi-Miner" operations.

DESCRIPTION OF FIELD WORK

During the period of November 10 - 19, 1986, the Surface Mining Laboratory conducted a study of the "Easi-Miner" operations at the Obed Mountain Mine in Hinton, Alberta. The purpose of the study was to obtain and process consecutive activities data to model and simulate the mining operations with continuous surface miner.

Only minimum site preparation was required for field study. The mine engineer and CANMET's staff marked sections of the seam with clearly visible markers. The markers were placed every 25m apart, outside of the "Easi-Miner" path along the variable length of the mined field. The trucks and "Easi-Miner" were observed while being operated during the day shifts of coaling activities.

Two types of cycle times were monitored: Easi-Miner and truck network cycle times:

1. Easi-Miner Cycle Times

The recording person was stationed inside the "Easi-Miner" cabin. During the study, the Easi-Miner operated in "circle cuts", "single cuts" and an "initial cut". Various cutting depths were used, the most common observed was 24 to 30 inches deep. A grader was also used in conjunction with the "Easi-Miner" to pile spilled coal, which was later picked up by the "Easi-Miner". An initial cut took a longer time than a normal cut and picking up windrows created by the grader was done at a considerably higher speed than the normal cutting operation. At the start and end of each cut, the cut depth depends on the operator and status of the trucks.

The total Easi-Miner cycle was reduced to two major components:

- times of turning to reverse into the new cutting and loading position (turnaround times), and
- delay times.

It was observed that the "Easi-Miner" loading time was identical to the trucks loading cycle, after completion of truck loading the movement of the "Easi-Miner" was stopped.

In addition to the basic time measurements the position of the "Easi-Miner" relative to the markers was recorded. The average speed of the "Easi-Miner" was then obtained.

The computer printout and listings of data on file used to evaluate and analyse this data are enclosed in the Appendix "A".

2. Truck's network cycle times:

The location of the Obed Mountain coaling operation during field work is illustrated in Figure 1. As shown, the coal cut by the "Easi-Miner" is hauled by trucks to the stockpile located outside the mining area.

Three Wabco-120C rear dump trucks with coal box capacity of 90t were assigned to the "Easi-Miner" during the field survey.

Seven basic measurements were recorded for each cycle:

- time between trucks arrival,
- truck's queuing time,
- spot time,
- load time,
- haul time (full travel time),
- dump time,
- return time (empty travel time).

The description of the truck cycle time were described early (1).

The computer printout and listing of truck's data are enclosed in the Appendix "A".

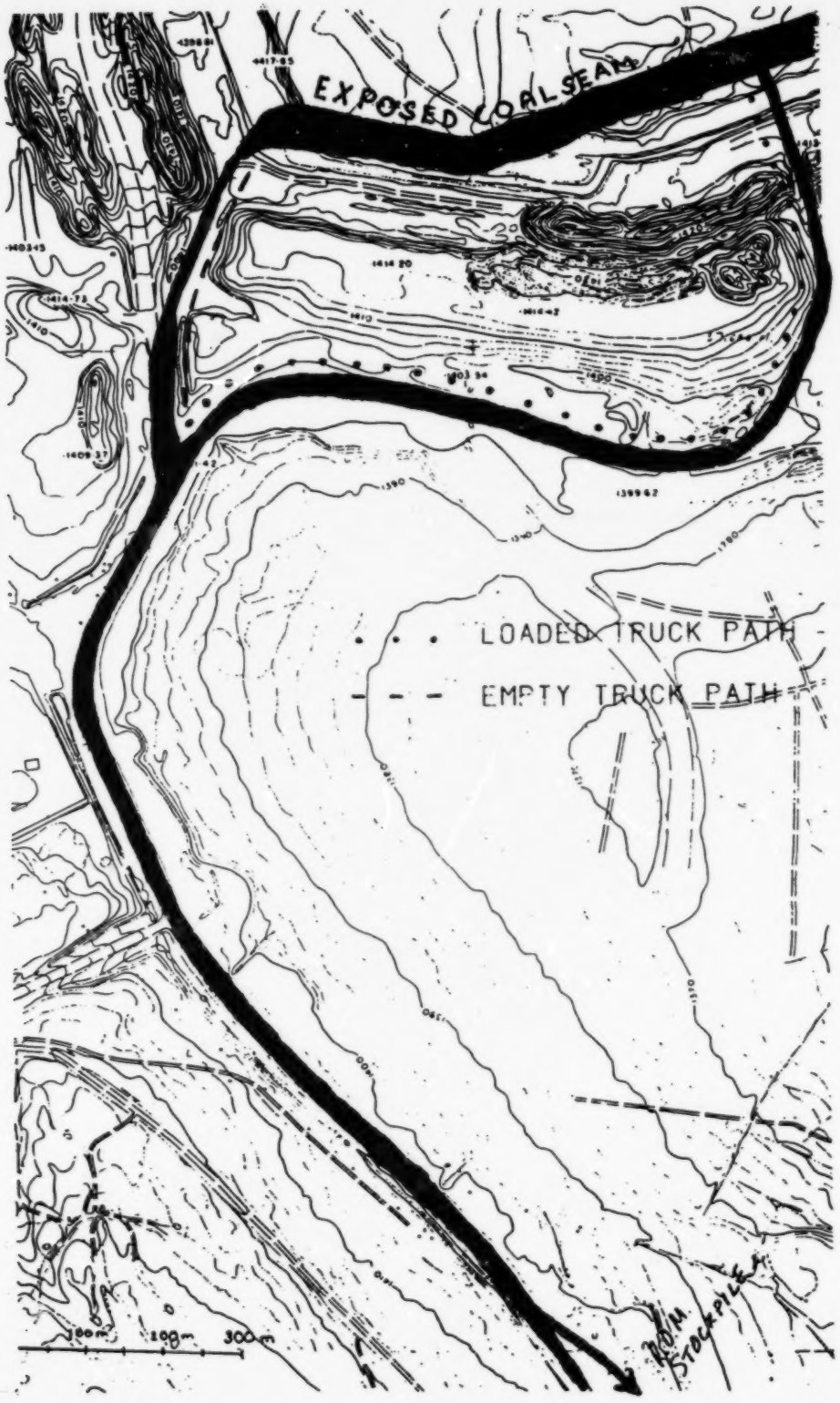

FIG. 1. THE LOCATION OF THE OBED MOUNTAIN COALING OPERATION DURING FIELD SURVEY

DATA ANALYSIS

In order to formulate a simulation model of the mining operation using the "Easi-Miner" the stochastic character of the resource "Easi-Miner" and network activities must be identified and modelled.

Tests on the validity of the chosen distribution was made on the maximum deviation of the plotted durations of the cycle components from their theoretical values. The residuals, when tested by the stabilized probability plot method (2), showed Weibull distributions.

A simple Weibull cumulative distribution function (c.d.f.) may be defined mathematically as follows:

$$F(t) = 1 - \exp\left(-(t-t_0)/\eta\right)^{\beta} \quad \text{for } t \geq 0 \qquad (1)$$

where:

$F(t)$ - fraction of times less than a given value,
t - cycle time,
t_0 - starting point or origin of the distribution,
η - characteristic life or scale parameter,
β - slope or shape parameter, and
e - exponential.

Estimation of the Weibull distributions parameters from the time study data were done using an in-house developed program. The program is written in FORTRAN and runs on a VAX 11/750 computer (3). The program estimates the parameters of a Weibull distribution by the rank regression and maximum likelihood technique. Table 1 shows the estimated Weibull distribution parameters for all components of time cycle, the plots of these probability density function and cumulative Weibull distributions are shown in Figures 2 to 37.

TABLE 1 - ESTIMATES OF PARAMETERS OF CYCLE TIMES FOR EASI-MINER (RESOURCE) AND TRUCK NETWORK CHARACTERISTICS OF THE WEIBULL DISTRIBUTION.

TYPE OF ENTITY	CYCLE COMPONENT (MIN)	DISTRIBUTION PARAMETERS BETA	ETA	MEAN (MIN)	STANDARD DEVIATION (MIN)
EASI-MINER	TURNAROUND	4.383	2.521	2.31	0.70
	DELAYS	0.897	6.120	6.88	8.51
TRUCK	TIME BETWEEN ARRIVAL	1.652	8.286	7.49	5.32
	QUEUEING	1.267	3.906	2.33	2.66
	SPOT	2.252	0.491	0.30	0.35
	LOAD	5.165	5.015	4.65	1.28
	HAUL	12.189	5.058	4.86	0.52
	DUMP	6.069	2.655	2.49	0.67
	RETURN	6.318	5.245	4.01	2.42

CONCLUSIONS

1. The Weibull distribution may be suggested as a time of each activities for Easi-Miner and truck's network.

2. Estimated values of the Weibull distributions parmeters for each of the activities in Obed Mountain coal mining operations with continuous "Easi-Miner" will create a base for the future development of the simulation model of that mining method.

ACKNOWLEDGEMENT

The authors are grateful to the Obed Mountain mine management and engineering personnel for their co-operation during data collection. Especially we like to thanks Mr. G. Acott, Chief Engineer and Mr. S. Lea, Senior Mining Engineer of the mine.

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2. Michael, J.R. "The stabilized probability plot", Biometrika, 70.1.pp.11-17; 1983.

3. Szymanski, J.K.' "Fortran Program for Weibull Parameter Estimation"; Division Report, ERP/CRL (in preparation).

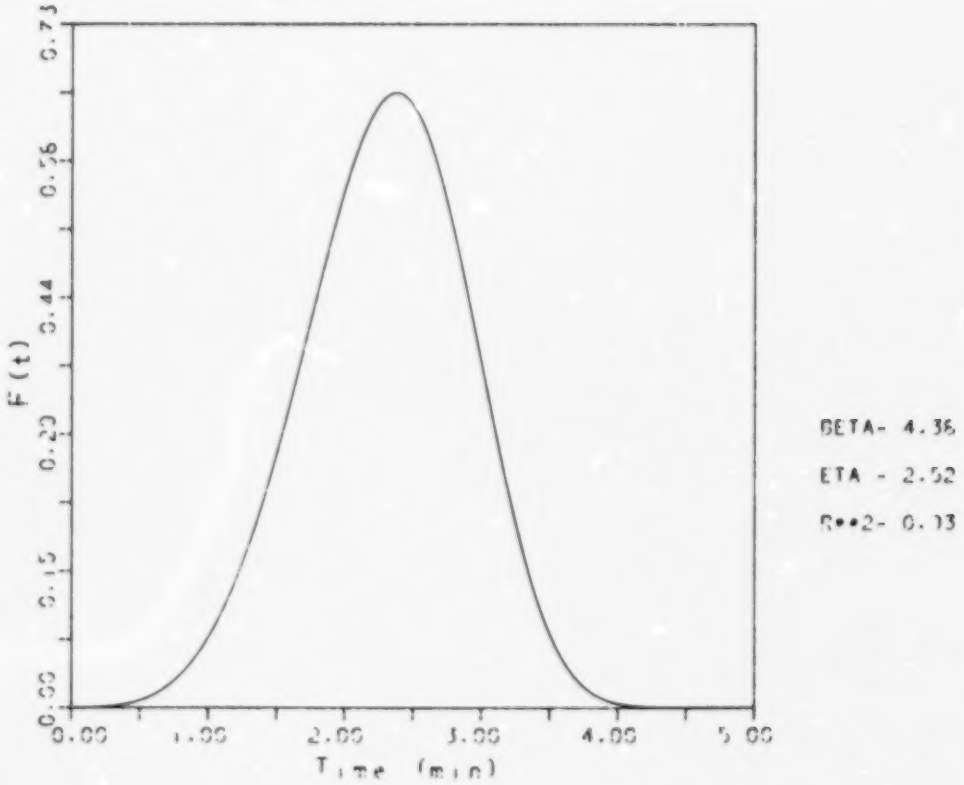


Fig. 2 - WEIBULL P.D.F. for EASI-MINER TURNS

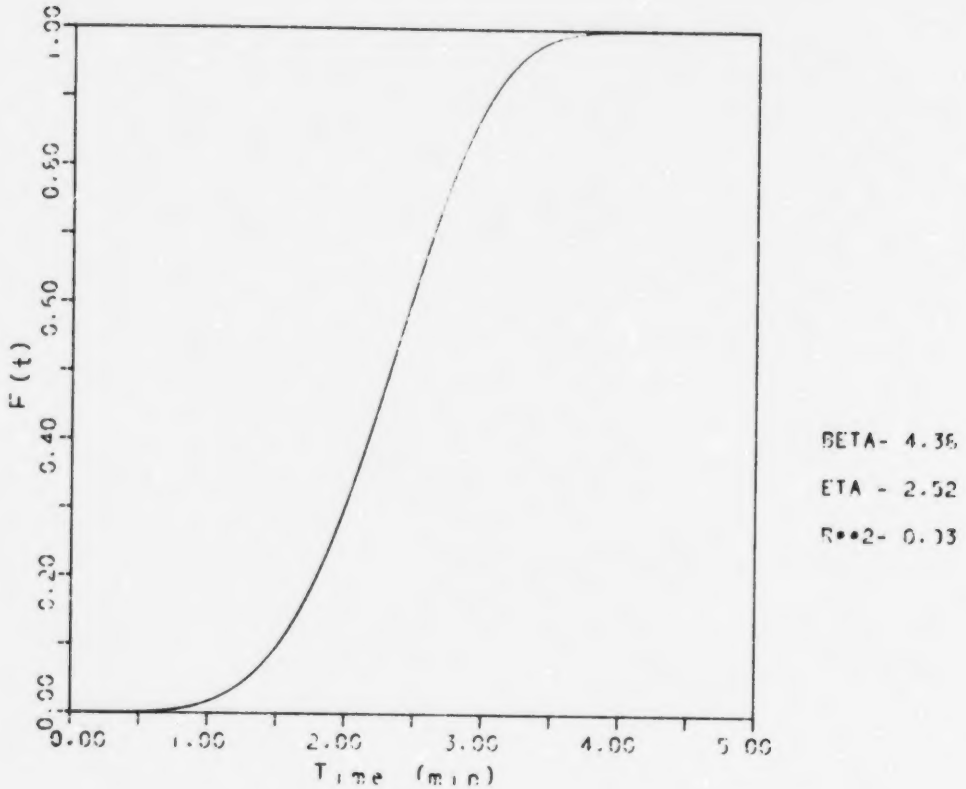


Fig. 3 - WEIBULL C.D.F. for EASI-MINER TURNS

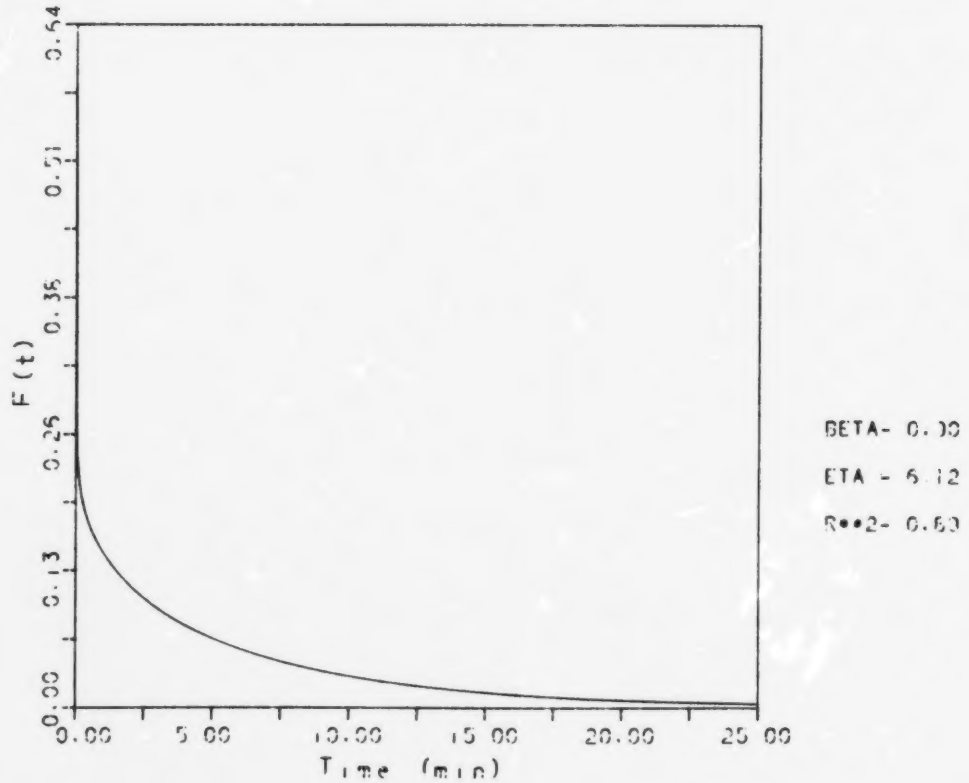


Fig. 4 - WEIBULL P.D.F. for EASI-MINER DELAYS

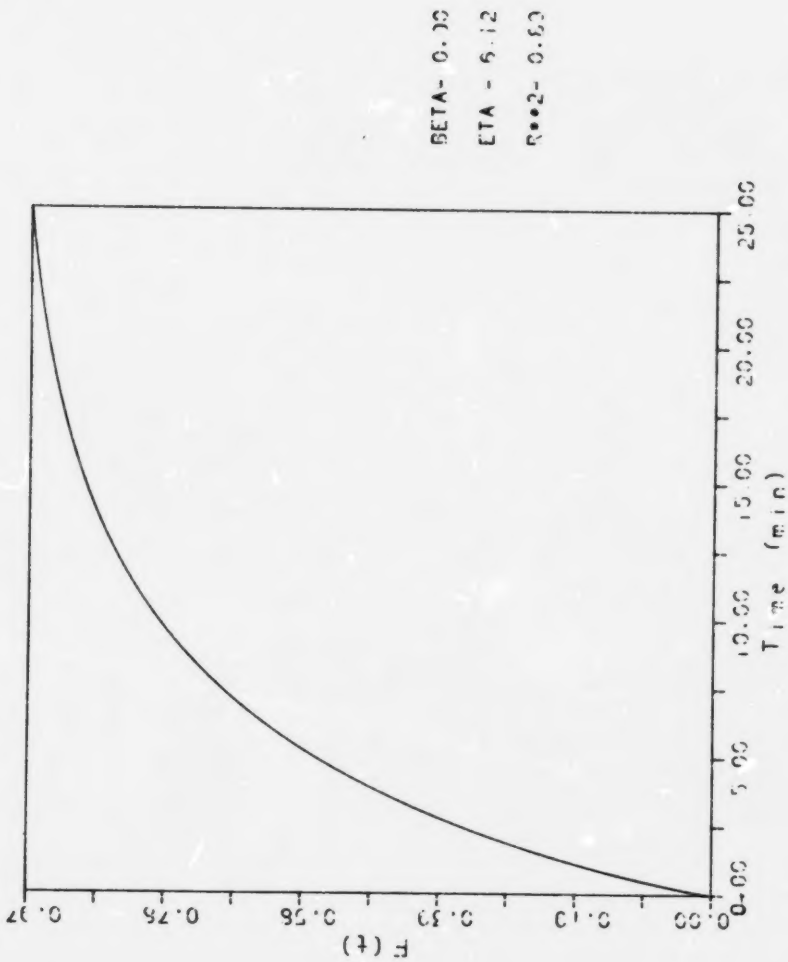


Fig. 5 - WEIBULL C.D.F. for EASI-MINER DELAYS

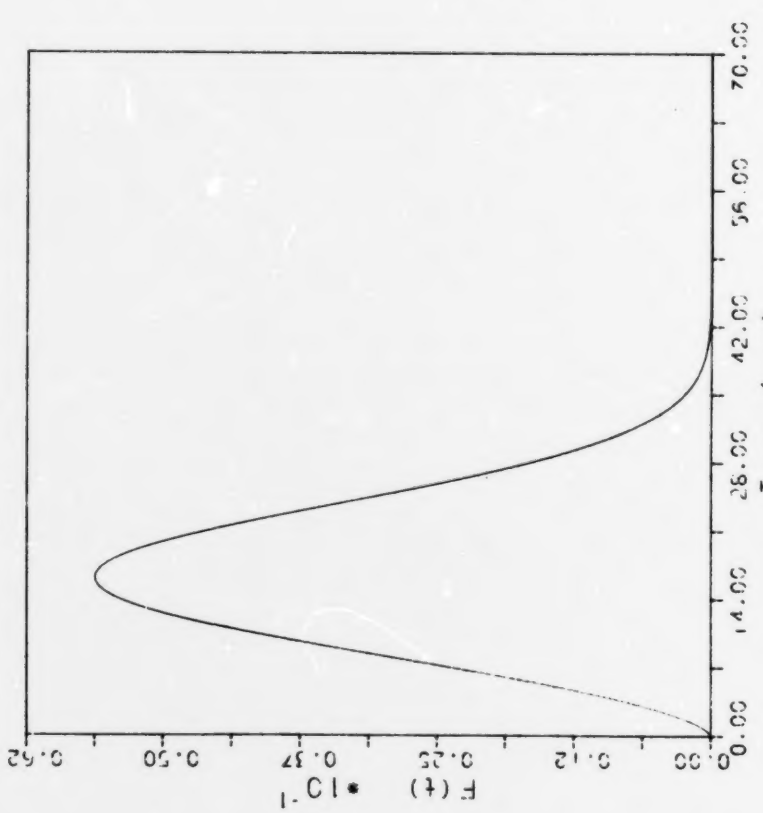


Fig. 6 - WEIBULL P.D.F. for EASI-MINER VELOCITY

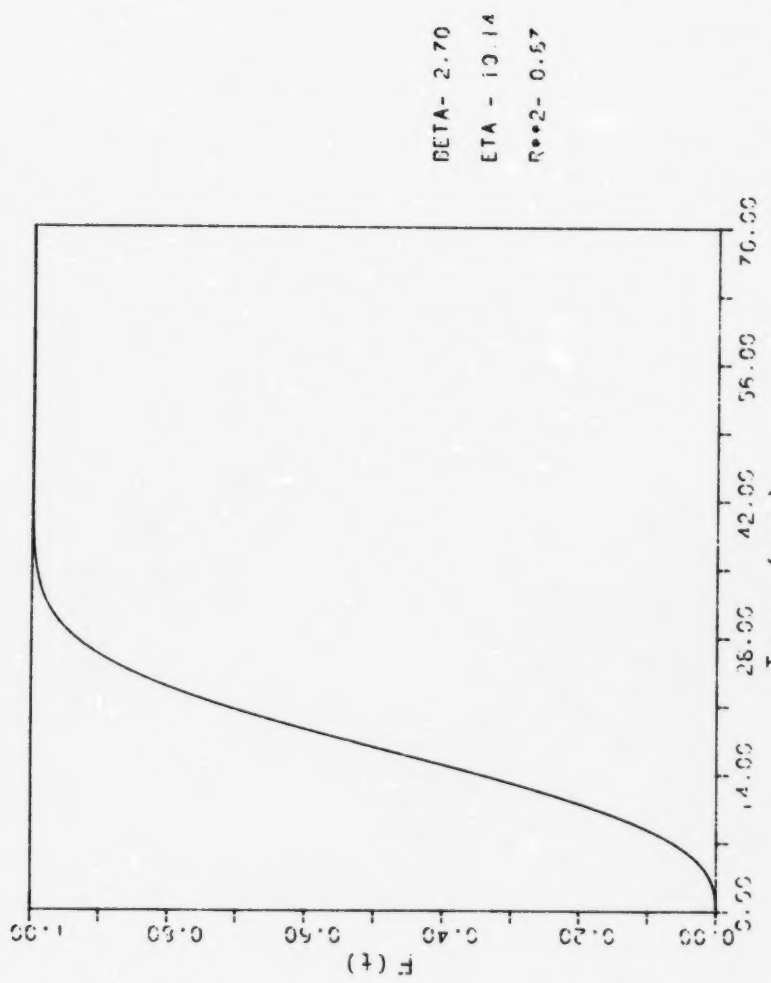


Fig. 7 - WEIBULL C.D.F. for EASI-MINER VELOCITY

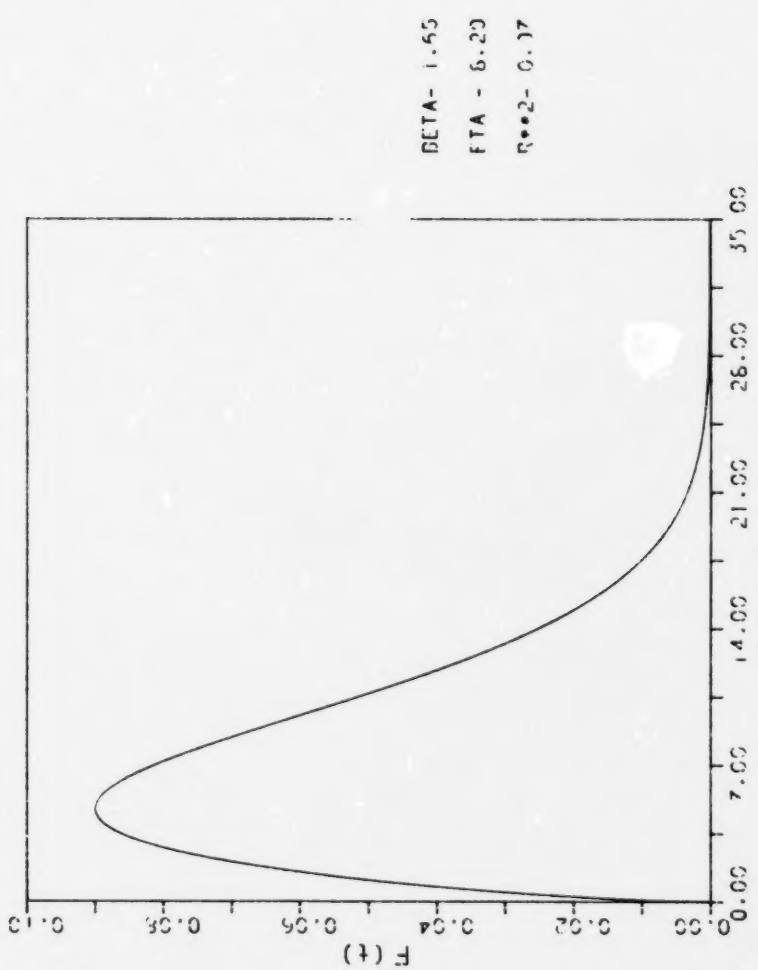


Fig. 8- WEIBULL P.D.F. for TRUCK ARRIVAL

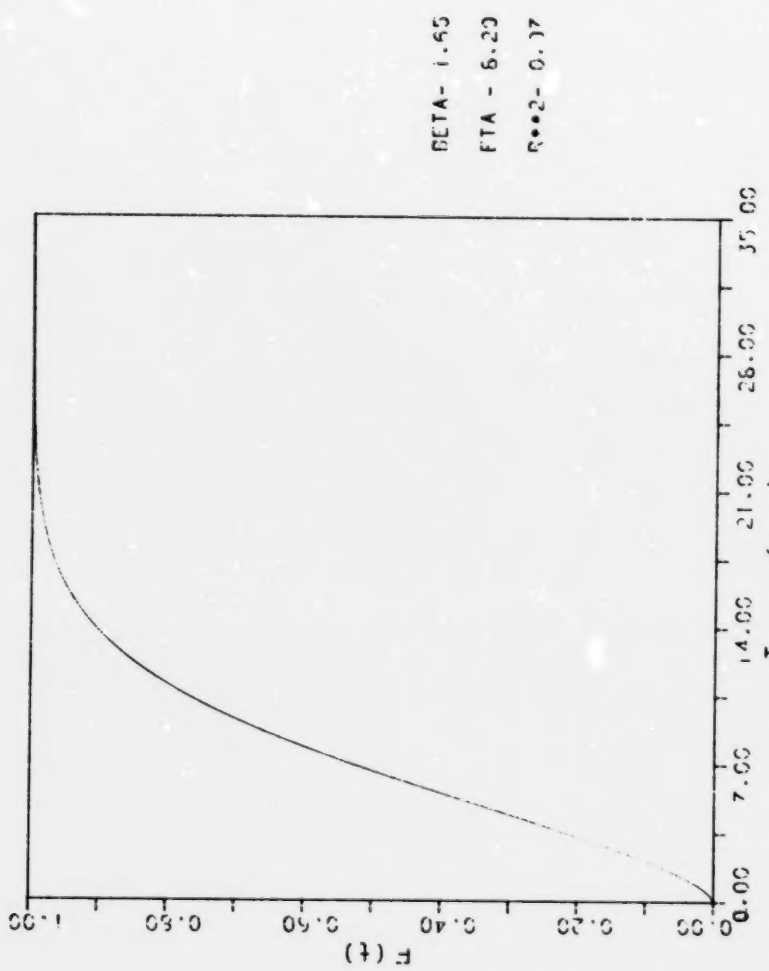


Fig. 9 - WEIBULL C.D.F. for TRUCK ARRIVAL

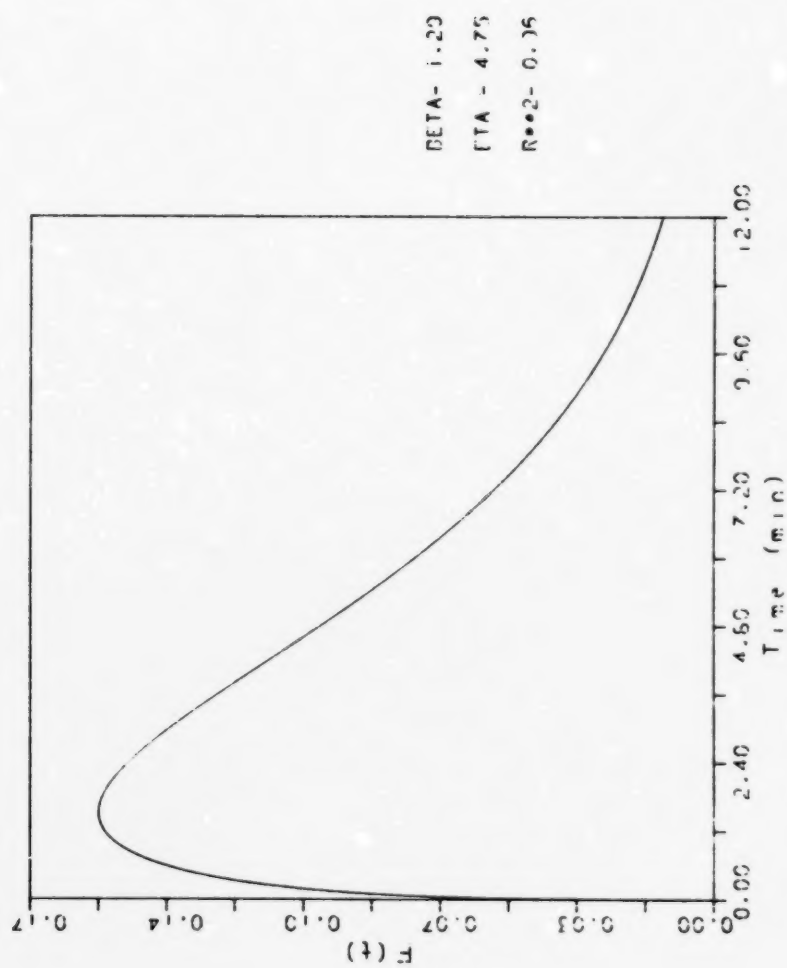


Fig.10 - WEIBULL P.D.F. for TRUCK QUEUE (TUE)

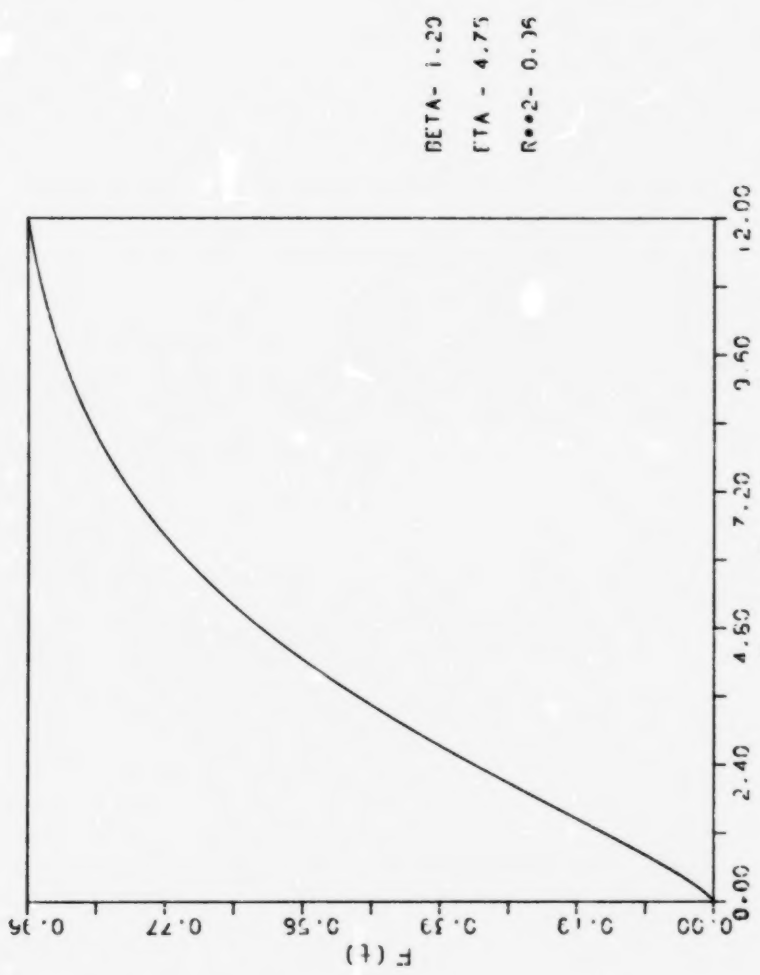


Fig. 11 - WEIBULL C.D.F. for TRUCK QUEUE (TUE)

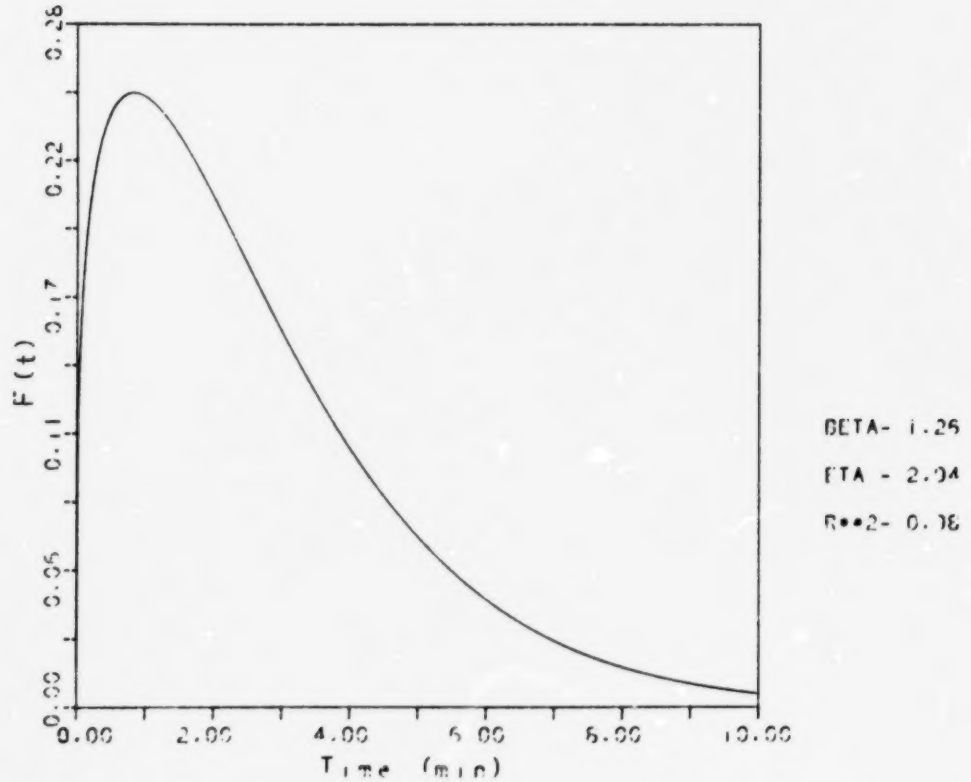
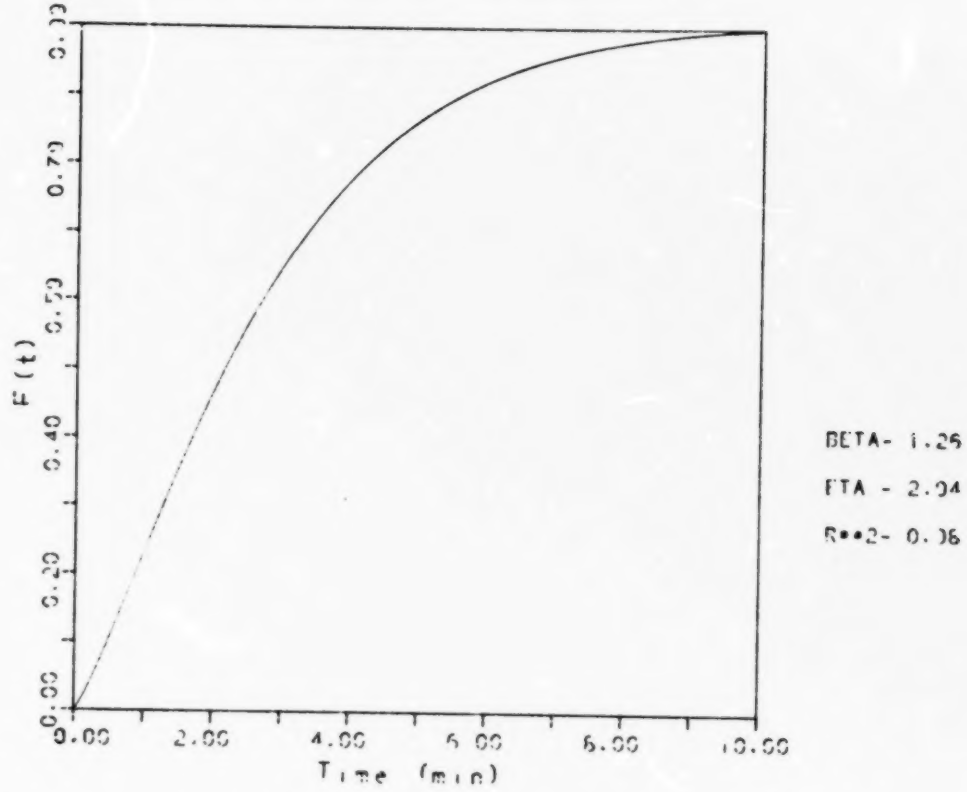


Fig.12 - WEIBULL P.D.F. for TRUCK QUEUE (WED)



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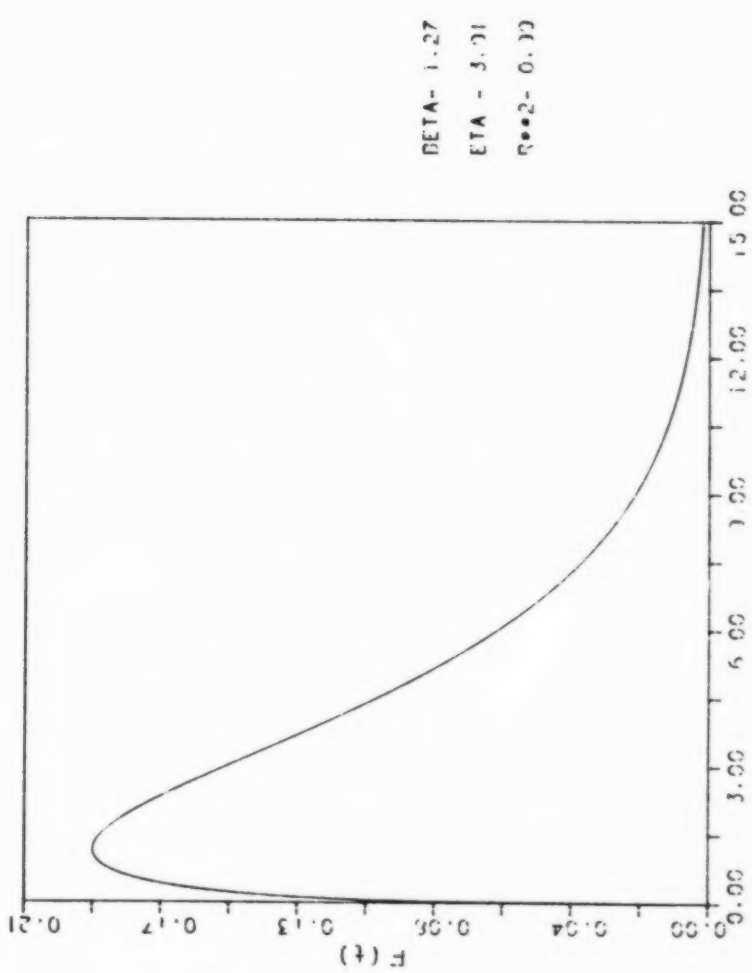
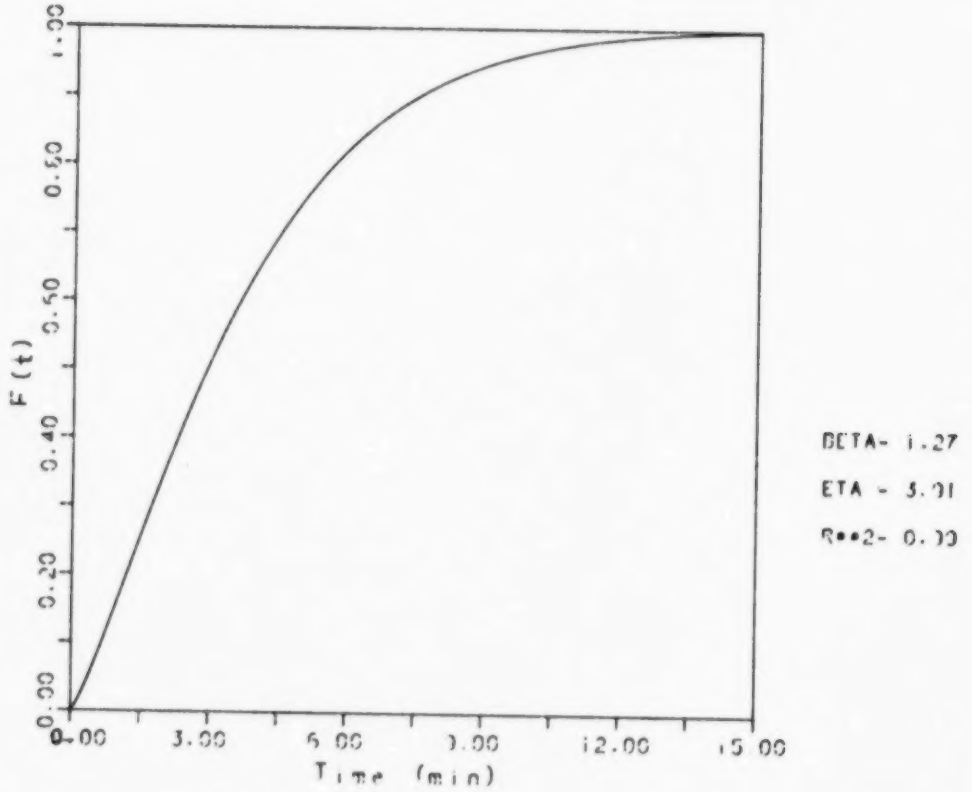


Fig. 14- WEIBULL P.D.F. for TRUCK QUEUE (TUE&WED)



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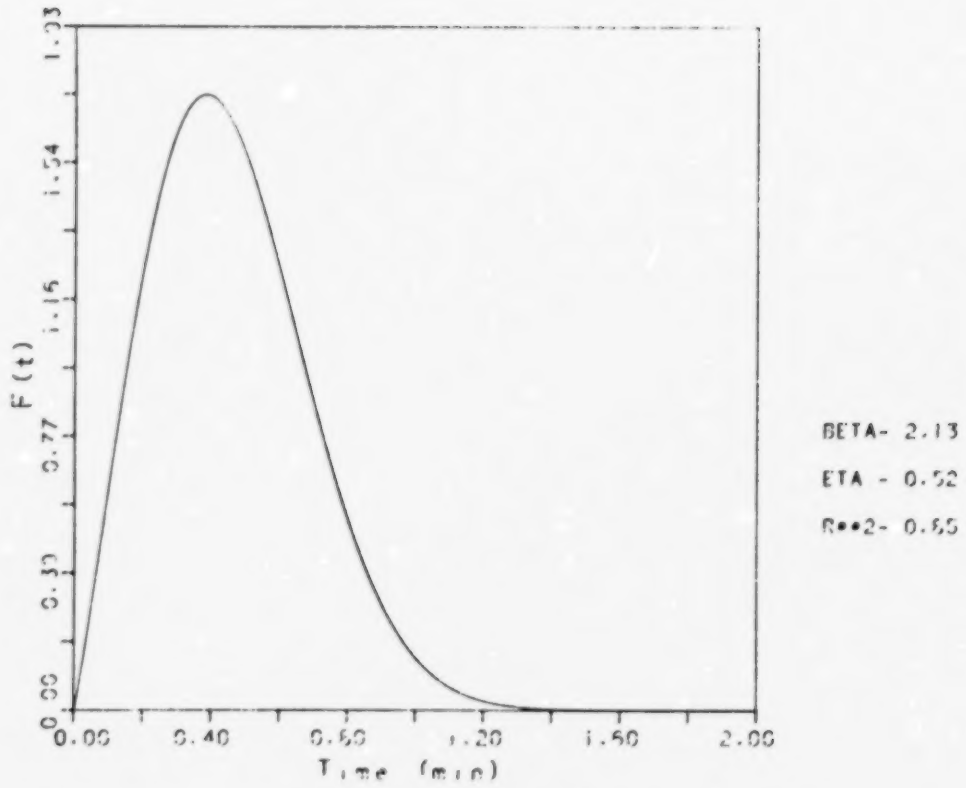

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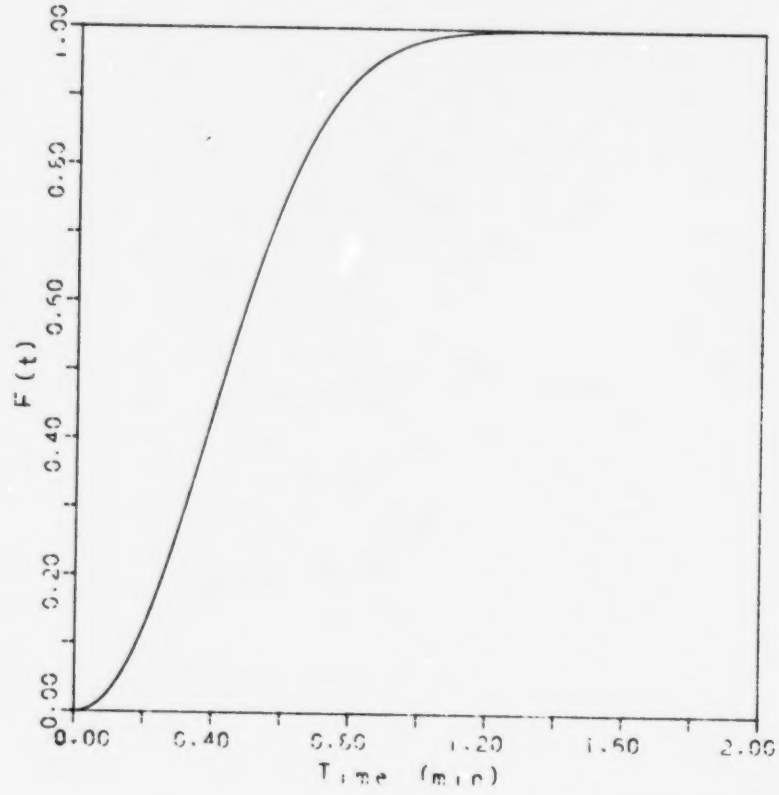

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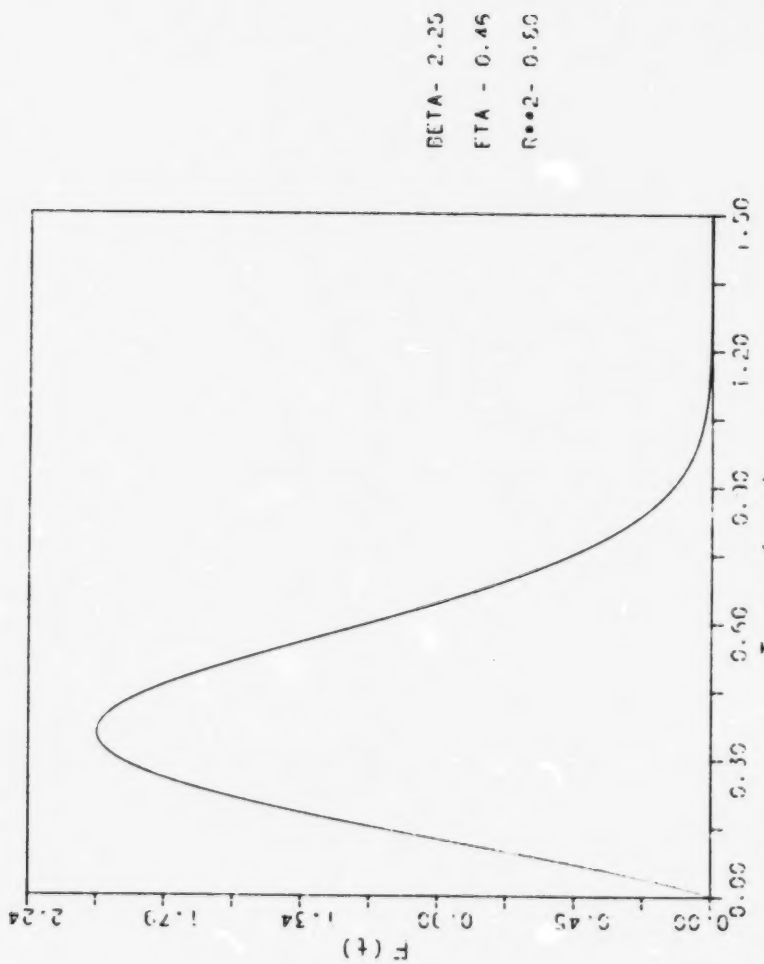

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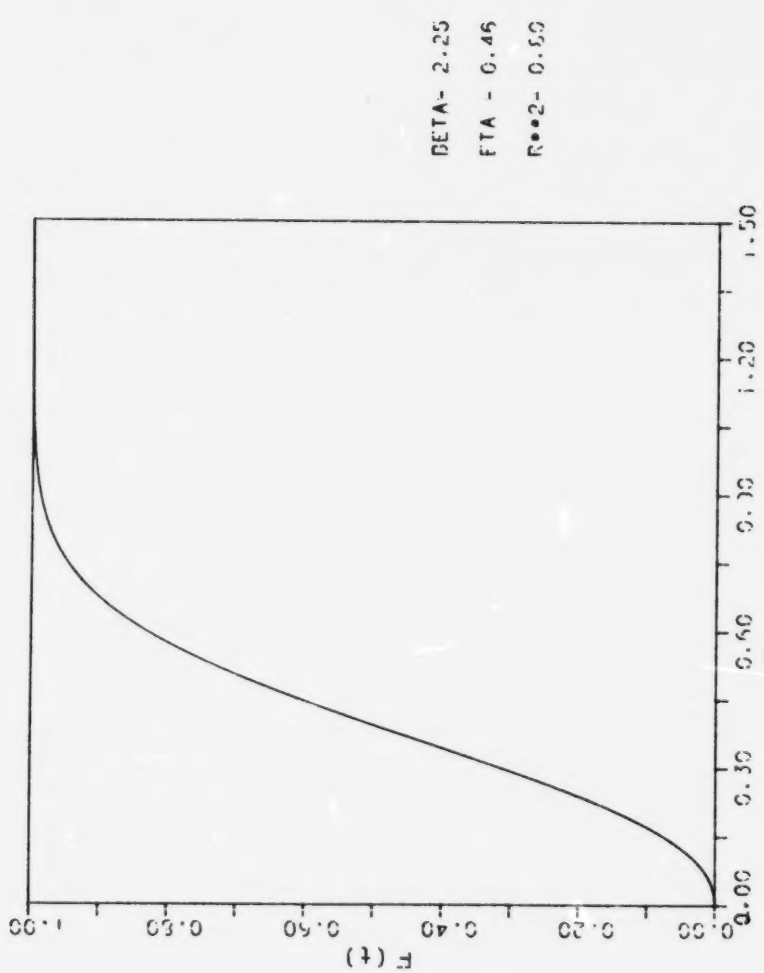

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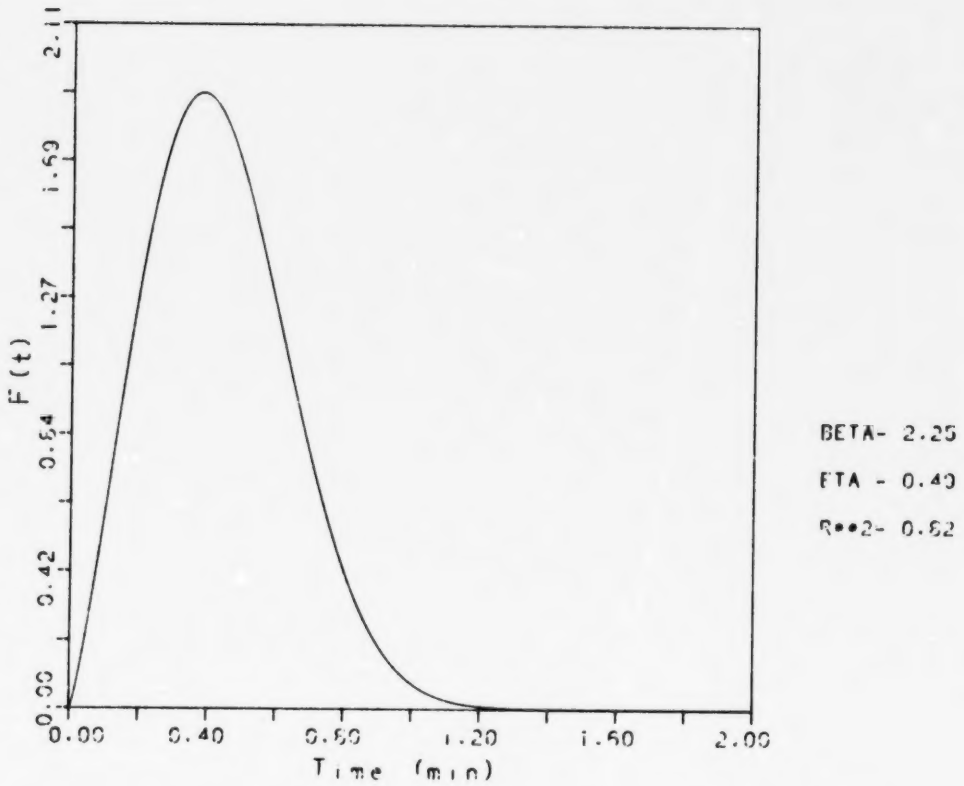


Fig. 20 - WEIBULL P.D.F. for TRUCK READY (TUE&WED)

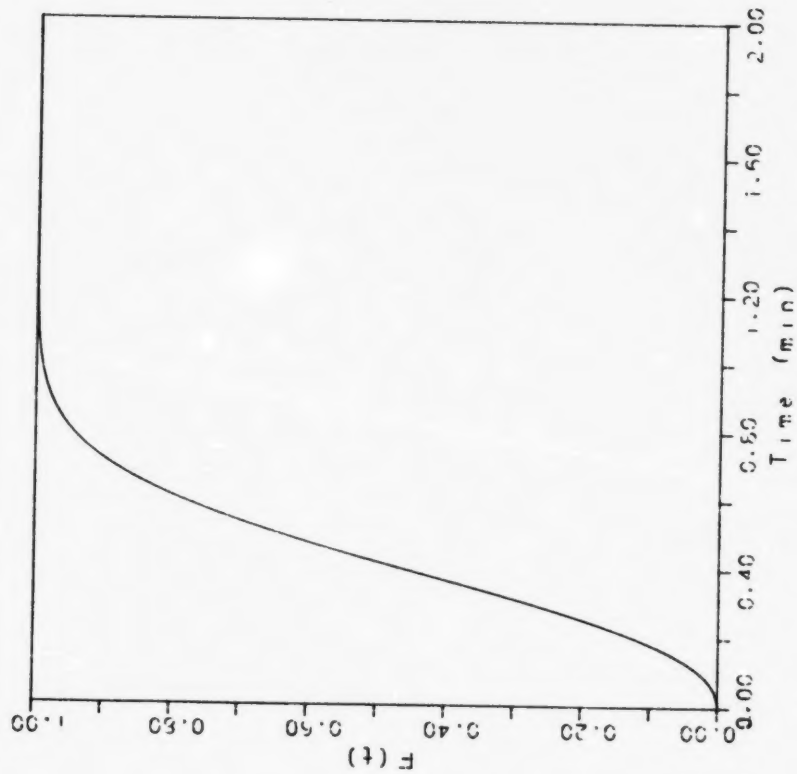


Fig. 21- WEIBULL C.D.F. for TRUCK READY (TUE&WED)

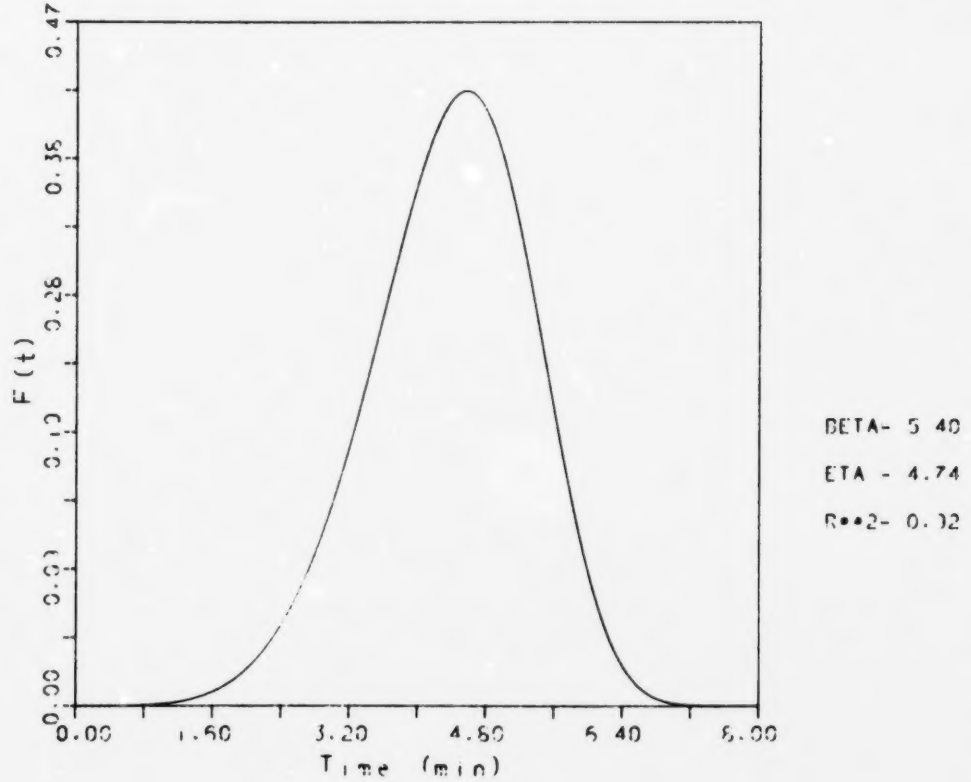
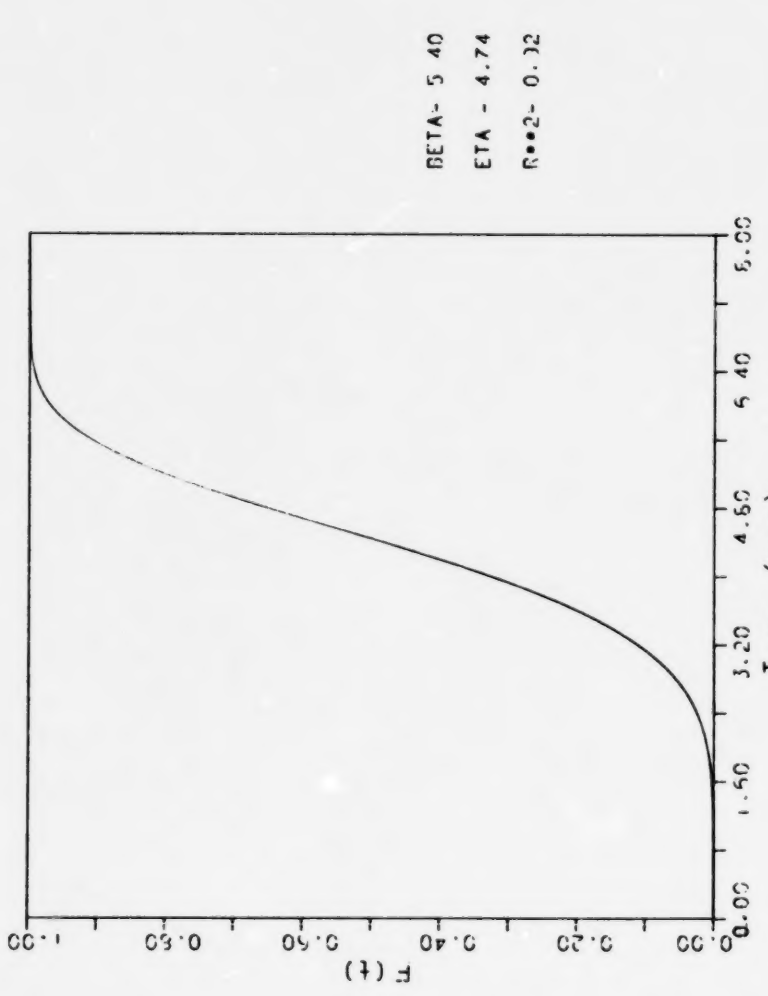


Fig. 22- WEIBULL P.D.F. for TRUCK LOADING (TUE)



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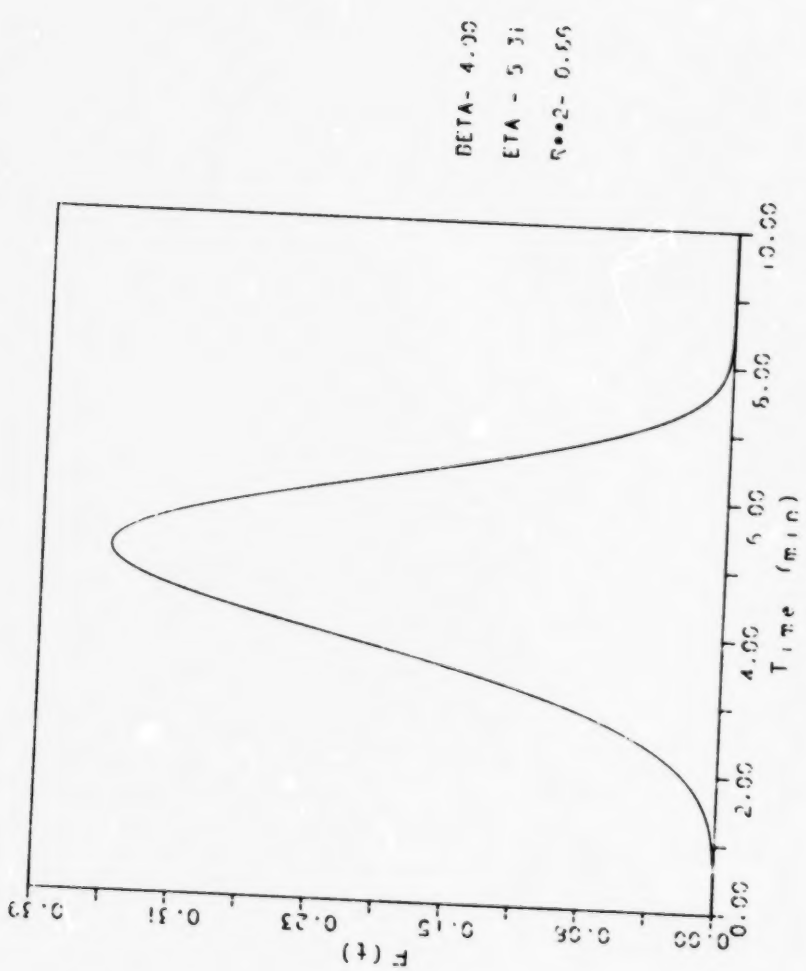

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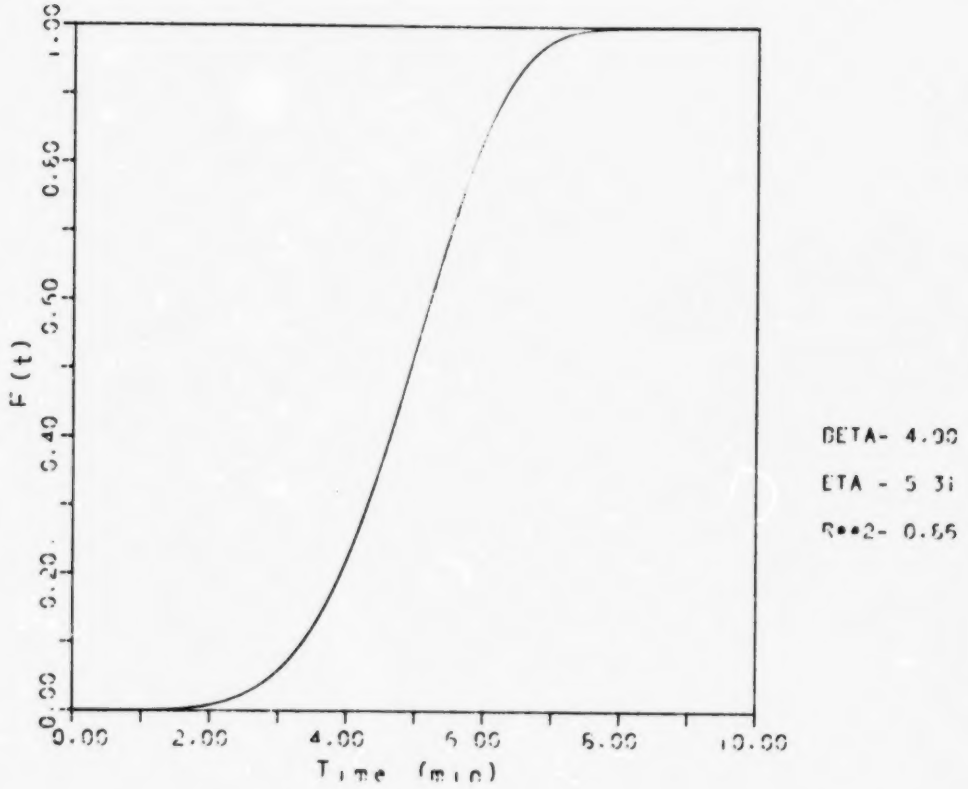

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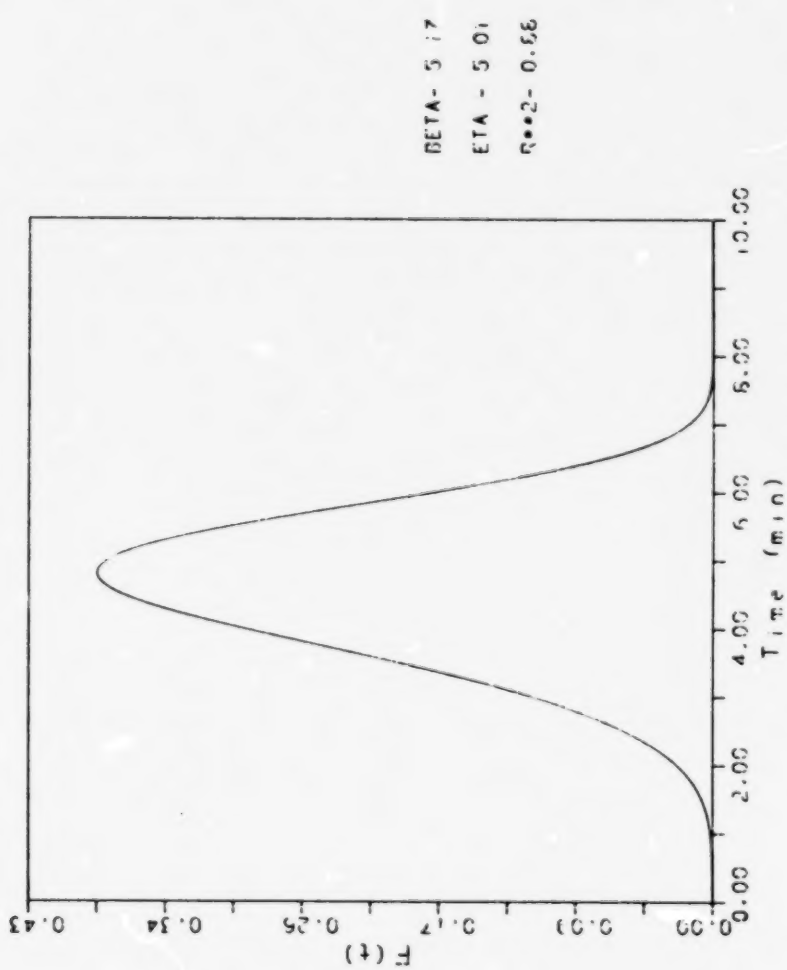

Fig. 26- WEIBULL P.D.F. for TRUCK LOADING (TUE&WED)

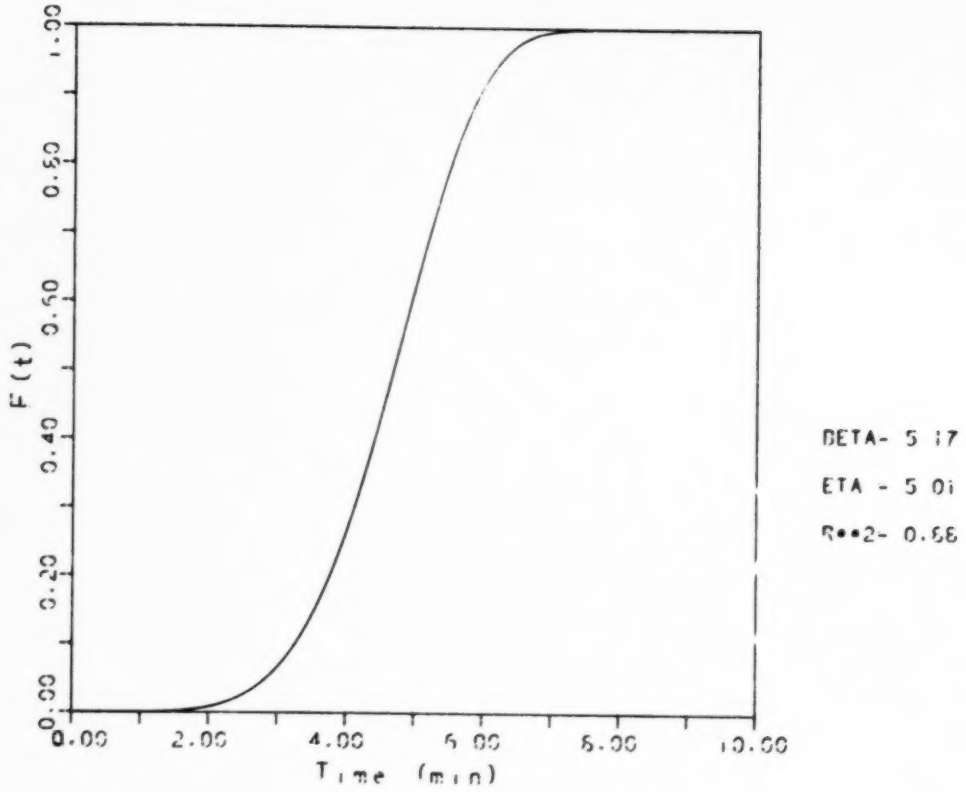

Fig. 27 - WEIBULL C.D.F. for TRUCK LOADING (TUE&WED)

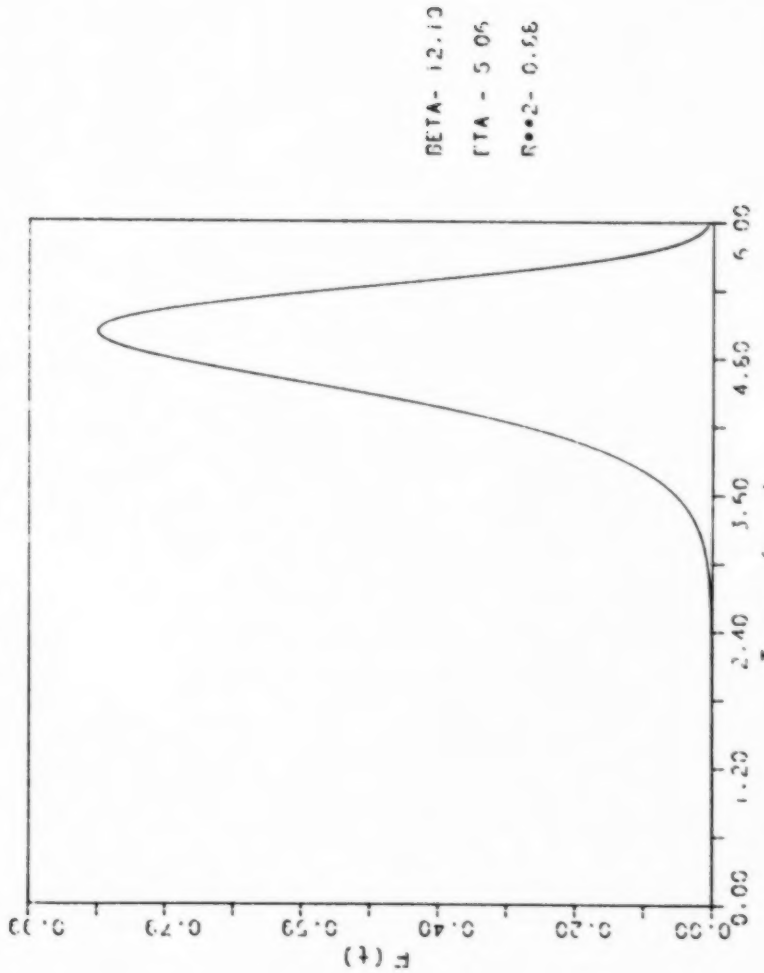

Fig. 28 - WEIBULL P.D.F. for TRUCK HAUL (WED)

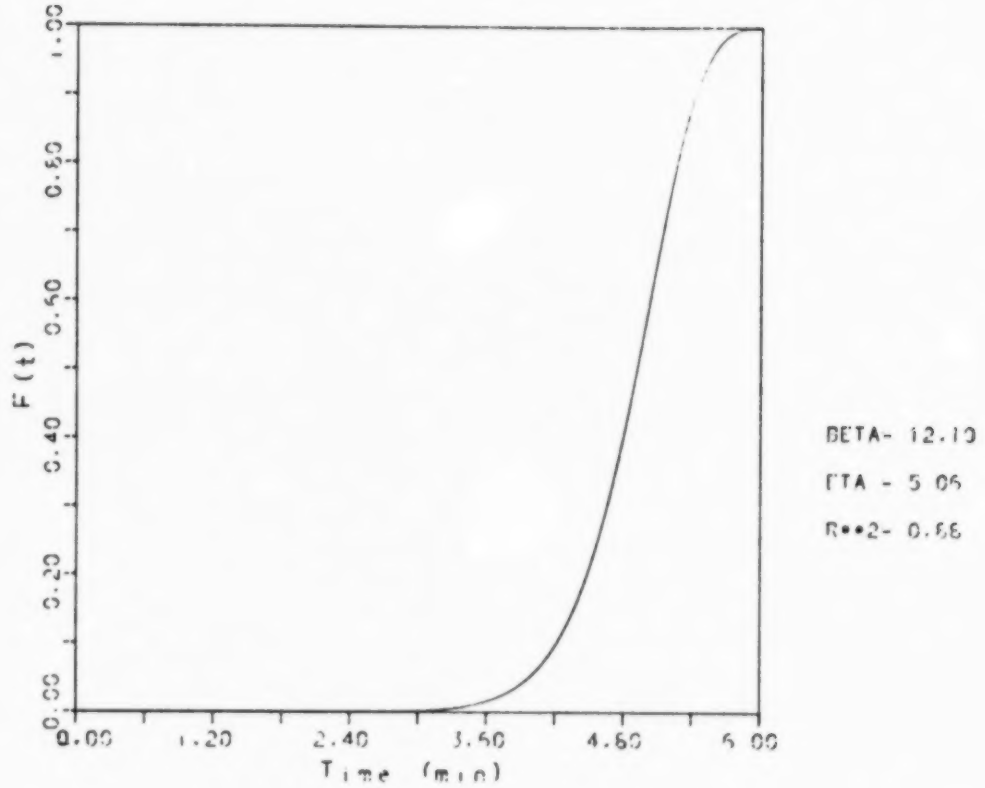

Fig. 29 - WEIBULL C.D.F. for TRUCK HAUL (WED)

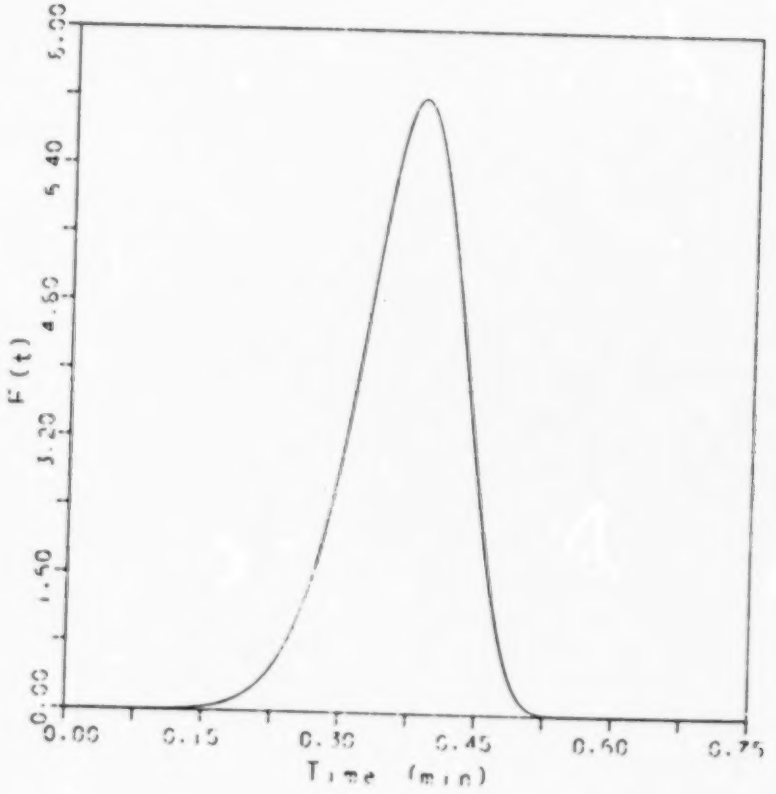

Fig. 30 - WEIBULL P.D.F. for TRUCK UNLOADING (WED)

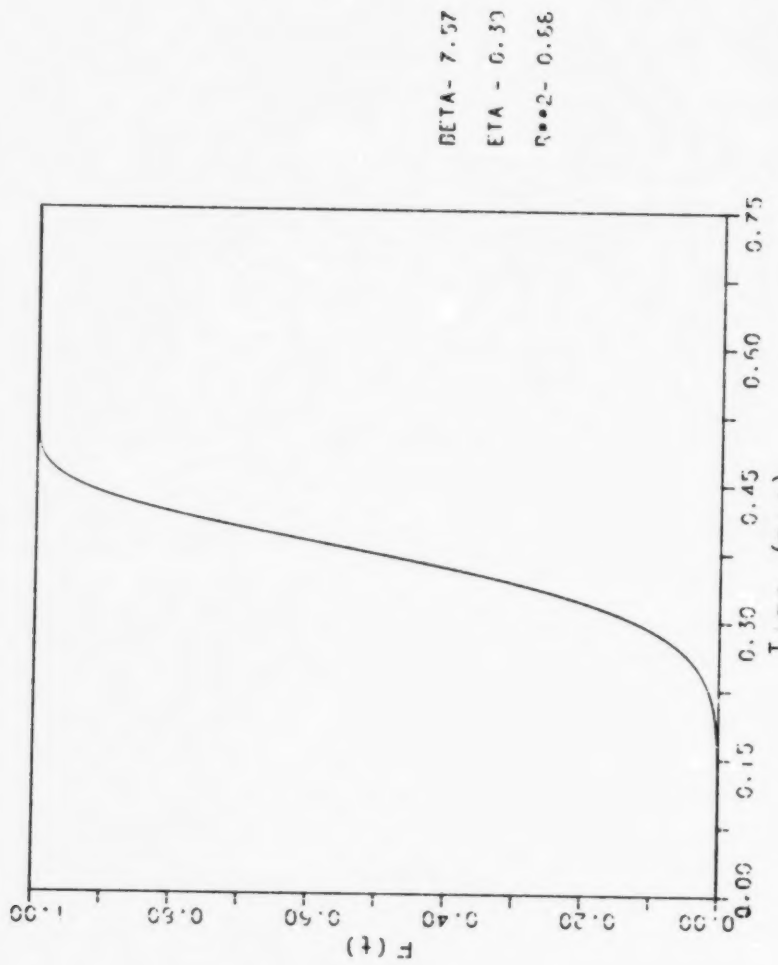

Fig. 31- WEIBULL C.D.F. for TRUCK UNLOADING (WED)

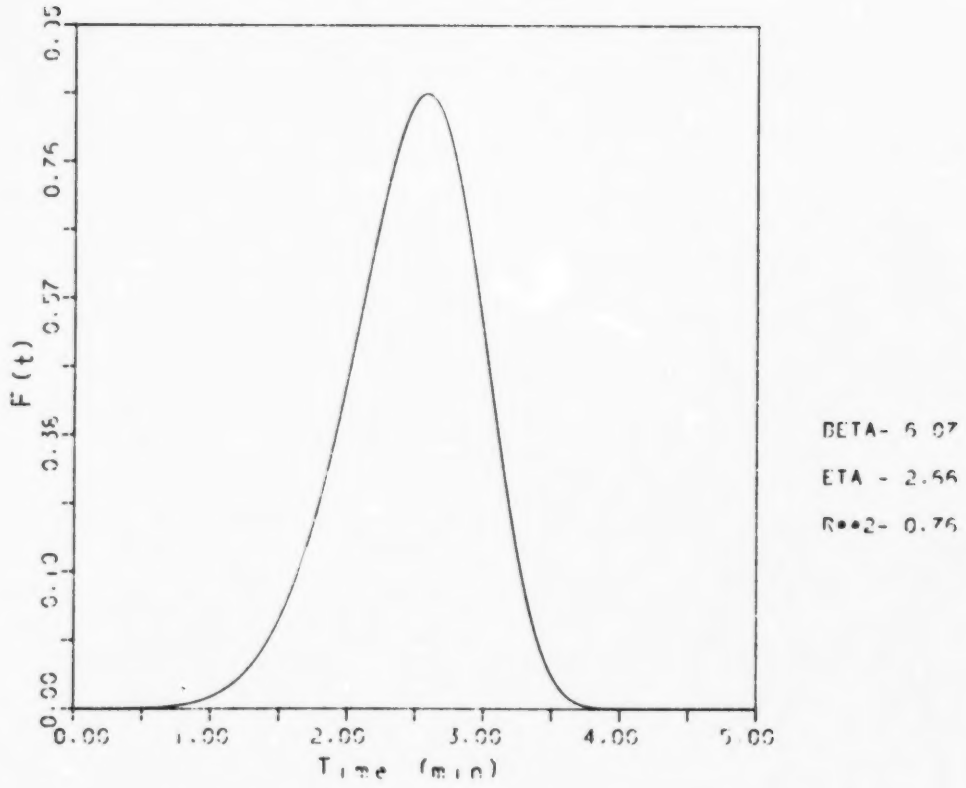

Fig. 32 - WEIBULL P.D.F. for TRUCK DUMP (WED)

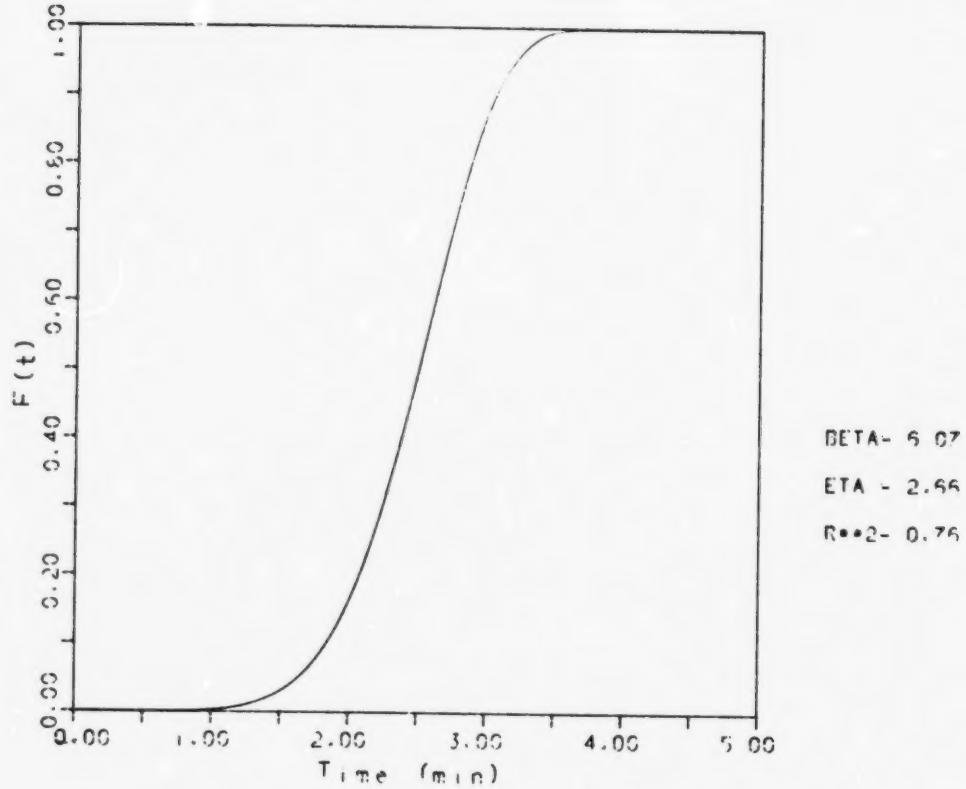

Fig. 33 - WEIBULL C.D.F. for TRUCK DUMP (WED)

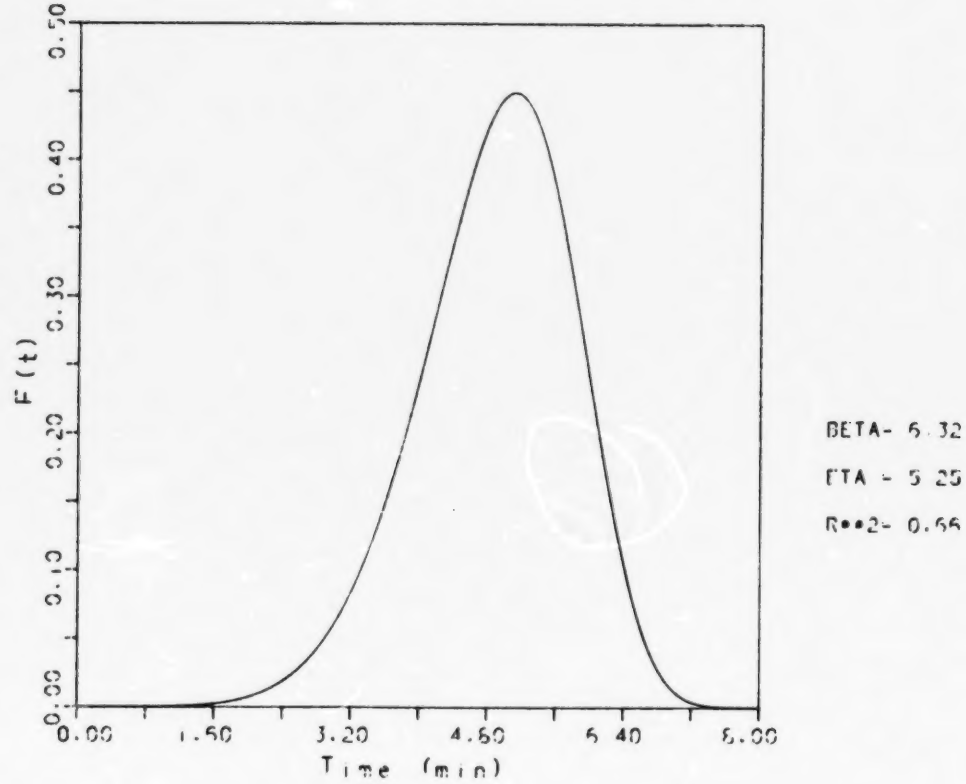

Fig. 34 - WEIBULL P.D.F. for TRUCK RETURN (WED)

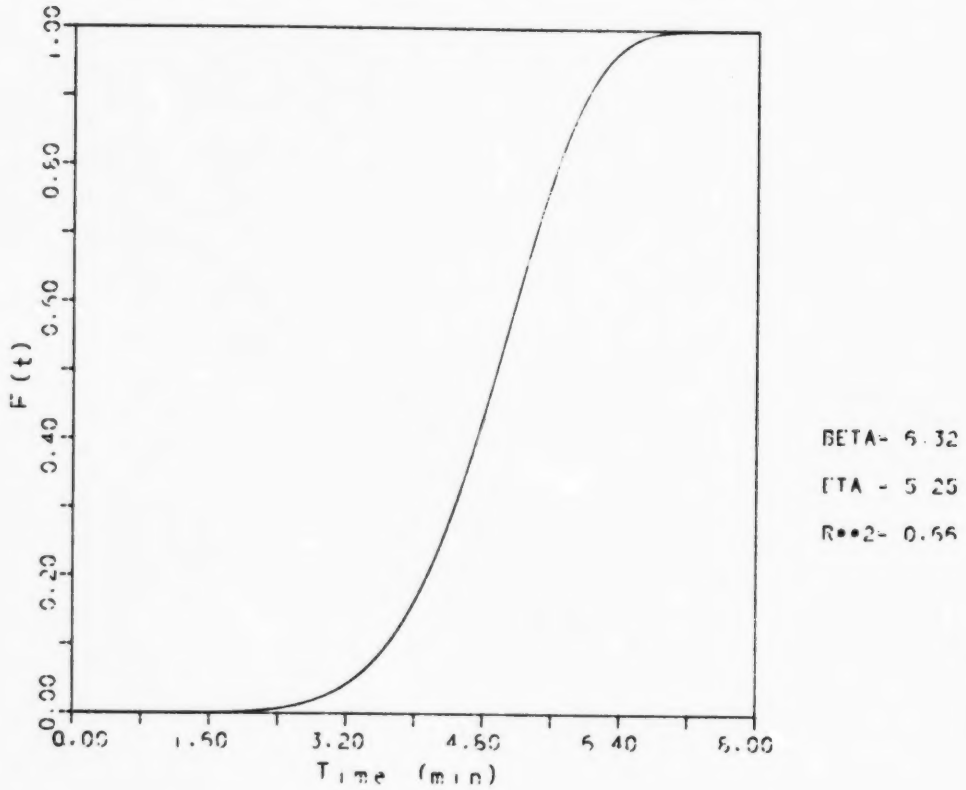

Fig. 35 - WEIBULL C.D.F. for TRUCK RETURN (WED)

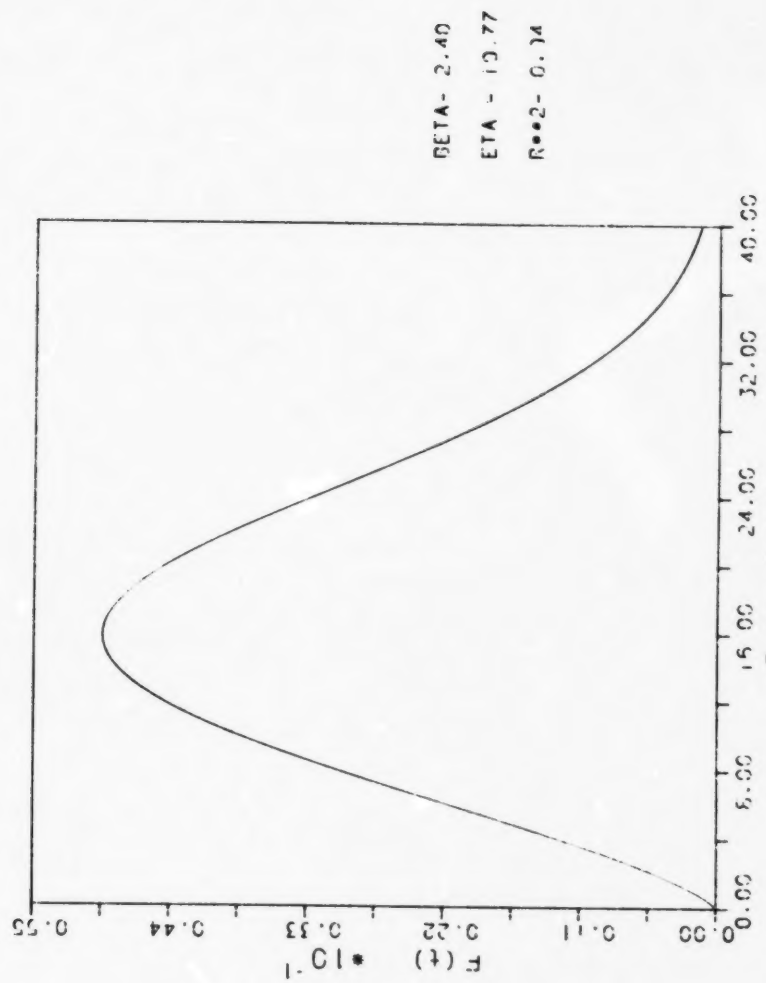

Fig. 36 - WEIBULL P.D.F. for TRUCK RETURN DELAYS

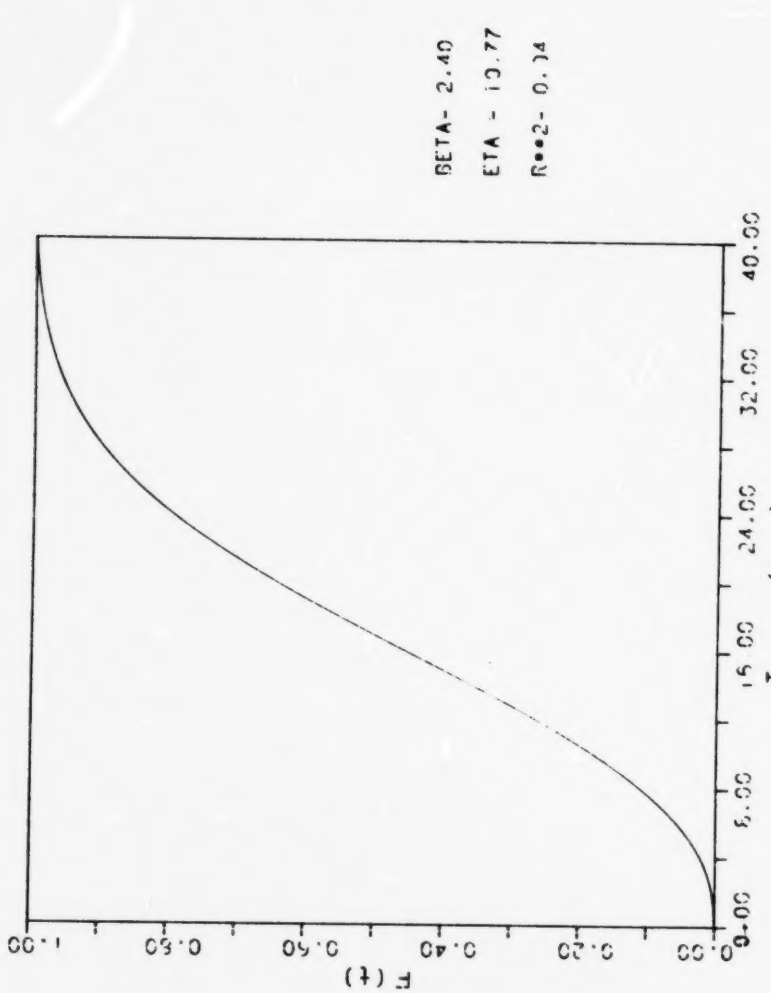

Fig. 37- WEIBULL C.D.F. for TRUCK RETURN DELAYS

APPENDIX A: PROCESSED TRUCK TIME DATA

FILE: ARRIVE.RED
TIME BETWEEN TRUCK ARRIVALS IN PIT (MIN.)

13.80
8.35
2.43
7.20
8.17
1.55
7.50
6.08
5.27
7.62
1.30
4.57
13.75
6.47
7.08
7.82
26.60
2.95
3.17
9.88
6.87
8.42
8.43
0.90
15.42
0.75
7.50
7.83
7.00
4.25
7.17
6.92
4.33
8.17
10.50
6.00
14.80
4.03
6.93
6.73
7.50
7.42
4.42
9.17
6.75

5.12
10.97
1.58
6.17
8.83
9.60
3.73
3.00
6.00
32.92
6.75
1.50
23.83
0.83
0.67
14.50
10.10
3.37
4.20
6.92
9.92
2.17
6.33
8.33
7.87
3.47
10.58
11.75
18.33
7.67
9.17
10.83
1.50
4.67
8.67
6.42
6.75
2.17
4.50
11.92
4.42
4.25

FILE: TUES.RED
TRUCK DATA FROM TUES (MIN.)

TRUCK	QUEUE TIME	READY TIME	LOADING TIME
1307.00	4.33	0.17	2.72
1304.00	2.10	1.03	3.50
1301.00	0.00	0.00	5.08
1307.00	1.33	0.67	3.52
1304.00	6.50	0.17	3.08
1301.00	1.33	0.42	3.25
1307.00	0.00	0.00	4.73
1304.00	1.17	0.17	5.00
1301.00	6.17	0.17	3.33
1307.00	7.67	0.25	5.00
1301.00	0.00	0.00	7.42
1307.00	3.00	0.25	2.92
1304.00	4.67	0.58	4.58
1301.00	0.00	0.00	5.88
1307.00	7.92	0.53	3.92
1304.00	11.70	0.30	3.33
1301.00	0.83	0.17	5.17
1307.00	0.00	0.00	4.07
1304.00	2.87	0.83	3.92
1301.00	3.42	0.30	3.70
1307.00	0.50	0.25	4.17
1304.00	0.00	0.00	5.00
1301.00	2.83	0.92	5.08
1307.00	4.83	0.33	3.42
1304.00	0.25	0.42	3.50
1301.00	0.00	0.00	4.63
1307.00	2.50	1.67	4.75
1301.00	2.25	0.58	4.25
1304.00	5.33	0.33	5.33
1307.00	5.00	0.30	3.87
1301.00	3.83	0.75	4.25
1304.00	0.17	0.25	4.42
1301.00	0.00	0.00	4.92
1307.00	3.42	0.25	3.00
1304.00	3.33	1.00	4.08
1301.00	0.00	0.00	4.17
1307.00	0.00	0.00	3.92
1304.00	0.00	0.00	4.58
1301.00	5.67	0.50	2.83
1307.00	4.50	0.33	3.50
1304.00	0.00	0.00	7.58
1301.00	8.50	1.17	3.50
1307.00	0.00	0.00	6.27
1304.00	8.00	0.50	5.50

1301.00	6.33	0.25	4.42
1307.00	4.17	0.33	5.67
1304.00	3.83	0.33	5.97
1301.00	6.30	0.70	4.17
1307.00	3.33	0.25	4.50

FILE: WED.RED
TRUCK DATA FOR WED (MIN.)

TRUCK NUMBER	QUEUE TIME	READY TIME	LOADING TIME	HAUL TIME	UNLOAD TIME	DUMP TIME	RETURN TIME	RETURN DELAY TIMES
1301.00	0.00	0.00	4.13	5.20	0.30	1.88	12.67	
1304.00	4.83	0.17	5.57	4.95	0.28	1.75	4.88	
1307.00	0.00	0.00	6.58	4.60	0.33	2.10	4.70	
1304.00	0.00	0.00	3.98	4.23	0.30	1.68	7.90	
1301.00	1.55	1.13	3.75	4.35	0.40	2.27	3.87	
1307.00	0.43	0.15	3.20	5.63	0.43	2.03	5.77	
1304.00	0.00	0.00	3.62	5.03	0.27	1.75	4.73	
1301.00	2.07	0.28	5.27	5.02	0.40	2.07	4.15	
1307.00	1.58	0.18	4.85	4.72	0.38	2.43	5.20	
1304.00	0.53	0.23	3.48	4.30	0.27	1.70	3.93	
1301.00	0.00	0.00	3.48	4.23	0.47	2.03	3.73	
1307.00	0.00	0.00	3.77	5.77	0.32	2.68	0.00	16.69
1304.00	2.47	1.27	2.88	5.07	0.42	2.15	4.48	
1301.00	2.05	0.38	3.73	4.87	0.38	4.60	4.58	
1304.00	0.00	0.00	4.13	4.23	0.33	2.18	0.00	32.42
1301.00	0.00	0.00	3.63	4.28	0.42	3.33	3.65	
1307.00	0.00	0.00	3.38	4.88	0.30	2.27	0.00	19.72
1301.00	0.00	0.00	3.83	4.63	0.47	4.78	0.00	14.69
1304.00	0.00	0.00	3.88	5.10	0.35	2.18	4.83	
1307.00	0.93	1.10	6.18	4.62	0.38	2.20	4.88	
1301.00	5.05	0.30	4.00	4.08	0.40	2.93	0.00	13.44
1304.00	0.00	0.00	4.62	4.23	0.33	2.18	4.25	
1307.00	0.00	0.00	4.28	5.83	0.32	2.15	4.58	
1304.00	0.00	0.00	4.43	5.25	0.33	2.18	0.00	8.10
1307.00	0.00	0.00	4.07	5.65	0.35	2.32	5.03	
1301.00	4.58	0.40	8.17	4.20	0.42	2.60	3.72	
1304.00	0.00	0.00	3.82	5.23	0.33	2.20	4.83	
1307.00	3.07	0.27	4.53	6.00	0.30	2.52	5.95	
1301.00	2.17	0.40	5.27	4.13	0.53	3.47	3.65	
1304.00	2.05	0.48	3.88	5.12	0.37	2.17	4.72	
1307.00	0.00	0.00	5.02	5.57	0.35	2.63	5.12	
1301.00	0.77	0.23	6.58	4.70	0.43	2.35	3.78	
1304.00	0.58	0.58	5.98	4.93	0.37	2.12	5.22	
1307.00	2.57	0.27	5.58	5.28	0.32	2.27	5.03	
1301.00	6.08	0.25	6.23	4.17	0.52	2.58	5.35	
1304.00	4.40	0.27	9.42	4.28	0.28	2.13	5.80	
1307.00	8.58	0.33	4.43	4.58	0.32	2.48	4.42	
1301.00	7.35	0.22	4.15	5.25	0.40	2.17	4.30	
1304.00	0.00	0.00	5.57	5.12	0.40	2.73	4.28	
1307.00	1.53	0.30	4.83	5.17	0.28	2.47	6.87	
1301.00	0.00	0.00	6.32	4.25	0.53	4.37	4.38	
1304.00	1.92	1.08	5.00	4.30	0.28	2.30	4.73	
1307.00	0.58	0.33	8.00	4.68	0.32	2.67	4.73	
1301.00	1.50	0.35	6.88	5.12	0.30	2.77	3.72	

1304.00	4.32	0.25	4.10	5.03	0.45	3.13	0.00
1307.00	0.00	0.00	6.92	5.52	0.38	2.65	0.00
1301.00	0.17	0.65	5.43	4.93	0.43	2.47	0.00

APPENDIX B: PROCESSED EASI-MINER TIME DATA

FILE: MISCDEL.RED
EASI-MINER DELAYS (MIN.)

14.58
4.03
0.78
1.03
22.87
2.87
1.97

FILE: TURNDEL.RED
EASI-MINER TURNING DELAYS (MIN.)

1.73
3.50
1.78
2.62
2.48
2.45
2.33
2.63
1.53
3.12
1.78
2.38
3.68
2.22
2.57
1.67
2.37
2.03
2.40
3.07
4.80
2.62
2.58
3.05
2.57
3.53
1.92
1.53
1.68
1.75
1.65
1.13
1.37
1.50
2.28
1.93
2.32
2.23
2.33
1.93
2.50
2.03
1.88

EASI-MINER DATA

DISTANCE (m)	TIME (min)	VELOCITY (m/min)
25.00	1.00	25.00
25.00	1.75	14.29
25.00	1.45	17.24
50.00	3.28	15.23
25.00	1.82	13.76
25.00	1.62	15.46
50.00	0.82	61.22
25.00	0.63	39.47
25.00	1.45	17.24
25.00	1.33	18.75
25.00	1.72	14.56
50.00	3.13	15.96
25.00	0.93	26.79
25.00	0.85	29.41
50.00	1.85	27.03
25.00	0.95	26.32
25.00	0.88	28.30
25.00	0.62	40.54
25.00	2.08	12.00
25.00	1.92	13.04
50.00	3.57	14.02
25.00	1.48	16.85
25.00	0.37	68.18
50.00	2.37	21.13
25.00	1.05	23.81
25.00	0.78	31.91
25.00	2.37	10.56
25.00	1.92	13.04
50.00	3.98	12.55
25.00	1.60	15.62
50.00	3.18	15.71
25.00	1.60	15.63
25.00	2.13	11.72
25.00	1.42	17.65
50.00	3.57	14.02
25.00	2.08	12.00
25.00	0.87	28.85
50.00	4.48	11.15
25.00	1.32	18.99
25.00	1.82	13.76
25.00	1.80	13.89
50.00	3.28	15.23
25.00	1.98	12.61
25.00	1.45	17.24
50.00	4.10	12.20
25.00	2.43	10.27
25.00	0.80	31.25
25.00	0.68	36.59
25.00	2.15	11.63
50.00	4.10	12.20
25.00	1.55	16.13
25.00	1.22	20.55
12.00	0.42	28.80
25.00	0.65	38.46
50.00	1.52	32.97
25.00	0.65	38.46
25.00	0.70	35.71
25.00	0.77	32.61
25.00	1.60	15.62
25.00	2.42	10.34
50.00	5.20	9.62
25.00	1.85	13.51
25.00	0.75	33.33

50.00	1.48	33.71
25.00	0.95	26.32
25.00	0.63	39.47
25.00	0.77	32.61
25.00	2.40	10.42
50.00	4.43	11.28
25.00	1.83	13.64
25.00	1.33	18.75
25.00	1.00	25.00
25.00	1.33	18.75
50.00	3.02	16.57
25.00	1.52	16.48
25.00	1.07	23.44
25.00	0.42	60.00
25.00	1.75	14.29
50.00	4.08	12.24
25.00	1.70	14.71
25.00	1.52	16.48
50.00	4.68	10.68
25.00	1.48	16.85
25.00	0.70	35.71
25.00	1.35	18.52
25.00	1.32	18.99
50.00	3.35	14.93
25.00	1.82	13.76
25.00	0.87	28.85
25.00	1.85	13.51
25.00	1.38	18.07
50.00	3.73	13.39
25.00	1.93	12.93
25.00	1.35	18.52
25.00	0.62	40.54
25.00	1.10	22.73
50.00	1.88	26.55
25.00	1.05	23.81
25.00	0.98	25.42
25.00	0.62	40.54
25.00	1.08	23.08
50.00	2.17	23.08
25.00	1.03	24.19
50.00	2.25	22.22
25.00	1.78	14.02
25.00	1.47	17.05
25.00	0.45	55.56
25.00	1.48	16.85
50.00	3.18	15.71
25.00	1.07	23.44
25.00	1.90	13.16
50.00	4.65	10.75
25.00	1.80	13.89
25.00	1.80	13.89
25.00	1.23	20.27
25.00	2.65	9.43
25.00	2.33	10.71
25.00	3.67	6.82
25.00	2.95	8.47
25.00	3.27	7.65
25.00	3.72	6.73
25.00	3.05	8.20
25.00	2.30	10.87
25.00	1.62	15.46
25.00	0.73	34.09
25.00	1.95	12.82
25.00	2.77	9.04
25.00	2.85	8.77
25.00	3.48	7.18

25.00	3.52	7.11
25.00	3.53	7.08
25.00	1.87	13.39
25.00	1.80	13.89
25.00	1.07	23.44
25.00	1.58	15.79
25.00	2.55	9.80
25.00	2.35	10.64
25.00	2.92	8.57
25.00	3.12	8.02
25.00	2.65	9.43
25.00	2.05	12.20
25.00	1.57	15.96
25.00	1.13	22.06
25.00	2.67	9.37
25.00	2.72	9.20
25.00	3.70	6.76
25.00	2.50	10.00
25.00	2.02	12.40
25.00	3.35	7.46
25.00	1.92	13.04
25.00	1.97	12.71
25.00	4.00	6.25
25.00	3.12	8.02
25.00	2.67	9.38
25.00	1.82	13.76
25.00	1.50	16.67
25.00	2.42	10.34
25.00	1.95	12.82
25.00	2.28	10.95
25.00	3.58	6.98
25.00	3.07	8.15
25.00	1.70	14.71
25.00	2.15	11.63
25.00	2.77	9.04
25.00	3.67	6.82
25.00	4.55	5.49
25.00	3.75	6.67
25.00	3.72	6.73
25.00	2.55	9.80
25.00	2.17	11.54
25.00	2.88	8.67
25.00	1.98	12.61
25.00	1.83	13.64
25.00	2.20	11.36
25.00	1.92	13.04
25.00	2.17	11.54
25.00	1.97	12.71
25.00	1.63	15.31
25.00	1.02	24.59
25.00	1.52	16.48
25.00	1.02	24.59
25.00	2.25	11.11
25.00	2.65	9.43
25.00	2.30	10.87
25.00	2.02	12.40
75.00	6.50	11.54
25.00	2.03	12.30